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CUMBERLAND RIVER STUDY

Environmental Protection Agency
Athens, Georgia

June 1972

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Interim Report

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Environmental Protection Agency
Region IV
Surveillance & Analysis Division
Athens, Georgia
June 1972

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SUMMARY

During the early spring of 1972, the 2,600 megawatt fossil-fuel powered Cumberland River power plant is scheduled to begin operation. To monitor the possible effects of the plant on the aquatic environment of the Cumberland River, the Environmental Protection Agency established a series of six stations upstream and downstream from the power plant. This is an interim report presenting the pre-operational data collected from the six stations in September 1971 and January 1972.

The power plant in full operation will utilize 4,200 cfs of water from the Cumberland River for cooling purposes. The 7-day 10-year minimum flow at the plant site is approximately 1,600 cfs. During the 13-year period of record, 7-day low flow values were less than 4,000 cfs during 6 years, the 14-day was less in 4 years, the 30-day was less in 2 years, and in 1969 the flow was less than 4,000 cfs for 90 consecutive days. The usable storage behind Cheatham Dam amounts to 19,800 acre feet, or 10,000 cfs days of water. During 4 of the 13 years of record, the mean discharge for 7 days was sufficiently low that a flow of 4,000 cfs could not have been maintained even if all of the storage was available and utilized.

The stations sampled are located 12 and 6 miles upstream from the power plant and 0.3, 3, 9, and 18 miles downstream from the plant. Dissolved oxygen, temperature, light transmission, and biological data were collected at each station during the two sampling periods.

Diel dissolved oxygen data indicate there is very little fluctuation in the dissolved oxygen during a 24-hour period in the fall and no detectable fluctuation in the winter. Dissolved oxygen concentrations during the fall were low, averaging about 50 percent saturation.

Maximum water temperature in the fall was 24.0°C. Temperature profiles at eight stations revealed good mixing throughout the river, even though the channel is very deep (50 feet). Temperature seldom varied more than 1 degree from top to bottom, generally about 0.5°C. January temperatures remained a constant 9.8°C. throughout the river.

The depth at which only 1 percent of the light entering the river remained, during the September sampling period, was 3.0 meters at Station CRM-115 and 2.5 meters at Station CRM-102.7. During the January sampling period, the 1-percent level was between 0.6 and 1.2 meters at both stations. The reduction in light penetration during the January sampling was primarily due to increased turbidity caused by extensive runoff from heavy rains.

Plankton and periphyton samples were collected from six stations on the river. The phytoplankton community was dominated by pennate and centric diatoms. Most of the organisms collected are adventitious plankters having their origin in the periphytic community. Total phytoplankton counts were low and revealed no significant differences among stations at the 0.05 level. The dominant algae and scarcity of organisms indicates a typical river situation.

Total periphyton counts revealed no significant differences among stations in September and January, but January counts were considerably less than those in September. Mean diatom diversity ($\bar{d}$) showed a significant difference among several stations in Setpember, but January data revealed no such differences. Based on equitability (e), most stations appear to be under a slight amount of stress; and the analysis of variance indicate there is a significant difference in the September data. Autotrophic index data indicate there are no significant differences among the stations in this study. A majority of the dominant diatoms are tolerant

of waters with high mineral content. Various parameter means suggest a general trend of slight perturbation at Stations CRM-85, CRM-94, CRM-109, and CRM-115 with a more disturbed situation at Stations CRM-100 and CRM-102.7.

A total of 950 macroinvertebrate organisms belonging to 24 families were collected from the overbank area on each side of the river from six stations in September 1971. Quantitatively, Tubificidae dominated all stations; and qualitatively, the Chironomidae dominated all stations. Generally, the macroinvertebrate community showed some sign of stress with mean diversity, $\bar{d}$, values ranging from 2.2 to 3.5 and equitability, e, values ranging from 0.4 to 0.7.

Fish samples were collected with an electric fish shocker at one station 12 miles upstream and at one station 0.3 mile downstream from the plant. Fish collecting consisted of three half-hour units of effort on each side of the river at each station both day and night. This 12-hour sampling effort produced a total of 2,107 fish, belonging to 32 species and 10 families. The downstream station produced considerably higher numbers of fish and total biomass than the upstream station. Two main types of cover were rock-strewn shorelines and stumps combined with other woody debris. The rock-strewn habitat supported the most abundant fish fauna.

Considering all parameters, the portion of the Cumberland River within the confines of this study appears to be a relatively "healthy" stream supporting abundant and diverse communities of plankton, periphyton, macroinvertebrates, and fish but showing slight signs of stress, probably due to moderate organic pollution.

INTRODUCTION

In 1968 the Tennessee Valley Authority began construction on a fossil fuel power plant on the Cumberland River near Cumberland City, Tennessee. This plant will consist of two units which will ultimately produce 2,600 megawatts of power and use cooling water from the Cumberland River at the rate of 4,200 cubic feet per second. The first of these two units is scheduled to go on line in early 1972, with the second unit following soon after.

The increasing use of natural waters for industrial cooling presents a real threat to aquatic resources in public waters. In 1980, it is estimated that approximately 6 percent of the average daily runoff in the United States will be utilized by the electrical power industry for cooling water (7). If the expansion of electric power production proceeds at the projected rate, by the year 2000 the electrical power industry will be using 50 percent of all available fresh-water runoff. Already Federal and state authorities have placed limitations on maximum temperatures of natural waters; however, many Southern waters approach maximum survival temperatures under natural conditions. Since the heat waste of a single 1,000-megawatt unit can raise the temperature of a river carrying a flow of 3,000 cfs by 10°F., it is obvious that many of our waters could become uninhabitable to existing aquatic populations. Realizing the urgency for collecting information which will help ecologists and engineers cope with this problem, personnel from EPA initiated the Cumberland River Study.

The objective of this study is to document the effects that a power plant of this size has on the aquatic community of a river such as the Cumberland. This is an interim report which describes the preoperational aquatic populations in the vicinity of the power plant site.

METHODS

The preoperational sampling program of EPA consisted of two sampling periods--September 1971 and January 1972. The September sampling period was selected so sampling ould be carried on during the most critical natural period for aquatic organisms--that is, low water levels combined with high water temperature. The January sampling period was chosen to document the influence of heated effluents on aquatic organisms during cold-water periods. Post-operational sampling will take place yearly at the same two intervals unless conditions dictate otherwise.

Detailed information on field sampling methods and laboratory analyses are presented in Appendix A and B.

OTHER STUDIES IN PROGRESS

A cooperative study between TVA and the Tennessee Game and Fish Commission was initiated in 1970 to monitor the effects of the Cumberland steam plant on the physical, chemical, and biological characteristics of the Cumberland River. In the study, water temperatures are being monitored continuously in the river throughout the vertical profile at the following TVA stations: CRM-90.01R, CRM-101.60R, CRM-102.02R, CRM-102.49L, CRM-103.2L, and CRM-106.51L. Water quality was monitored at three stations (CRM-120.0, CRM-102.49, and CRM-80.0) during the preoperational phase of the study. In this portion of the study, temperature, dissolved oxygen, pH, and alkalinity were measured through the vertical profile. In addition, samples were collected in midstream at the surface, mid-depth, and 2 feet from the bottom and were analyzed for fecal and total coliforms; pH; alkalinity; color; turbidity; threshold odor; BOD (5-day, 20°C.); COD; nitrogens (organic, ammonia, nitrite plus nitrate); soluble and total phosphate; calcium; magnesium; hardness; specific conductance; iron (ferrous, filterable, and total); manganese (filterable and total); sodium; potassium; silica; sulfate; chloride; flouride; and solids (suspended and dissolved). These samples have been collected at various intervals; and beginning in December of 1971, two additional stations (CRM-65.0 and CRM-50.0) were added to the study.

Biological sampling stations are located at river miles (RM) 115.0, 109.0, 106.0, 104.0, 103.0, 102.4, 100.5, 98.6, 95.0, 90.0, and 85.0 and two stations in Wells Creek. Starting in 1972, three more stations (CRM-80.0, CRM-65.0, and CRM-50.0) will be sampled. Van Dorn bottle grab samples of water for phytoplankton and zooplankton are collected at 1-, 3-, and 5-meter depths

at mid-channel. They are then separated by filtering, and the zooplankton are quantified. Phytoplankton are counted directly. A general index of quantity and photosynthetic activity of the phytoplankton is estimated by determining chlorophyll content, numbers of genera and cells, dominant and sub-dominant forms, percentage composition of orders, and carbon fixation. Artificial substrates are used to study the periphyton community. These are allowed to incubate for a period of time; the attached material is then removed from the substrate, identified, and analyzed to determine an autotrophic index. Macroinvertebrates are collected in three Ponar dredge samples from each overbank at each station. These organisms are identified and enumerated; size-age determinations will be made on most representative specimens.

Fish samples are being collected quarterly from six stations (CRM-109, CRM-106, CRM-103, CRM-100, CRM-97, and CRM-94) on the river. The sampling gear consists of 1½-inch bar-mesh gill nets and 4-foot hoop nets. Sampling consists of four gill nets and two hoop nets set at each station and fished for four consecutive nights at each station. In addition, meter nets will be employed to sample larval fishes. The objective is to determine species composition, relative abundance, growth, condition, and reproduction of fishes in the vicinity of the Cumberland steam plant before and after it becomes operational.

POWER PLANT AND SITE DESCRIPTION

The Cumberland Power Plant is located on the Cumberland River (RM 103.2) in Stewart County, Tennessee. It is located at the headwaters of Barkley Reservoir, 72.4 miles upstream from Barkley Lock and Dam (RM 30.6), Grand River, Kentucky. This will be the largest coal-fired power plant in the TVA system--consisting of two units, each with a rated capacity of 1,300,000 kilowatts. Operating at full capacity, it will use 1,896,000 gallons (4,200 cfs) of water per minute and will deliver 9.3 billion BTU's of heat per hour to the receiving stream which has a mean daily flow of 24,000 cfs. In 1970 the discharge from Cheatham Dam (RM 148.7) ranged from 116,380 cfs in January to 3,160 cfs in December (Table 1). The plant design is such that cooling water flowing across the condenser will rise 12°F. and pass through an effluent structure designed to float the water over the surface of the receiving stream. One-half mile below the outfall the heated water is expected to be 10°F. above the ambient water temperature.

DESCRIPTION OF STUDY AREA

The Cumberland River originates in the Cumberland Plateau of Pulaski County, Kentucky, then travels approximately 690 miles through Kentucky and Tennessee to empty into the Ohio River near Smithland, Kentucky. The area included in this study lies between river mile (RM) 85 and RM 115 (Figure 1). The bottom profile of the river throughout most of the study area is U-shaped with maximum depths ranging from 40 to 55 feet (Figures 2 through 11).

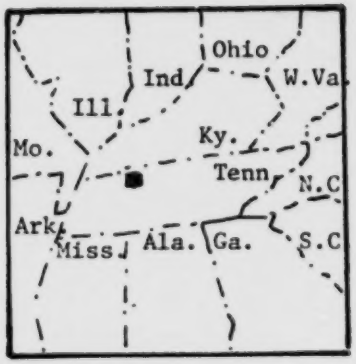
In the upper reaches of the study area (RM 115 to 94), the river runs through an area of alternating limestone bluffs covered with mature hardwoods and low mud banks lined with a narrow band of hardwoods backed by agricultural land. The gradient through this stretch flattens perceptibly at about RM 106.

In the lower reach of the study area, from RM 94 to 85, the gradient becomes quite flat, and the river begins to take on the appearance of an impoundment. The banks and backwaters are choked with cattail and other emergent aquatic plants.

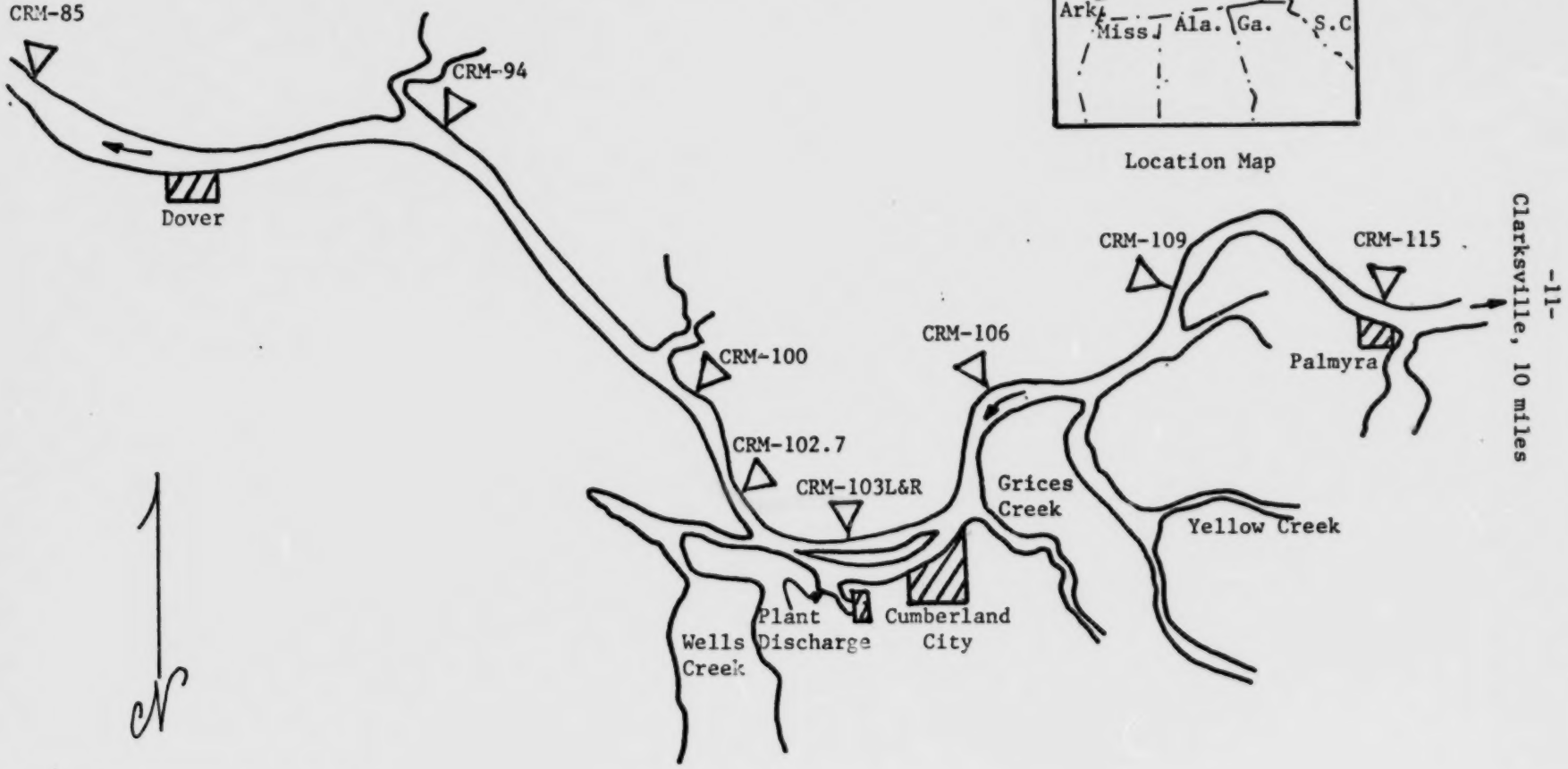
The recreational potential for the area is quite extensive. Fishing for crappie and black bass appears to be quite good, and utilization of established access points is high. The lower reach (downstream from RM 100) lies within the Cross Creek National Wildlife Refuge. As a result, there is a good concentration of waterfowl and, subsequently, good waterfowl hunting in the area. Pleasure boating is somewhat restricted as a result of heavy barge traffic and floating debris; however, there is some in conjunction with Indian artifact ("Indian rock") hunting.

Figure 1

VICINITY MAP



Location Map



Scale: Approx. 1" = 5 miles

DESCRIPTION OF STATIONS

Six stations corresponding to those in the TVA-Tennessee study were selected for this study. Each station has been given a river mile location (e.g., CRM-102.7), but is not restricted to a single point. Physical and chemical analyses are performed from point-source samples, as are the quantitative periphyton, plankton, and macrobenthos examinations. The fish and other qualitative biological data, however, are taken from a reach of the river that extends both upstream and downstream from the designated river mile.

The stations are divided into two groups:

1. Stations upstream from the power plant intake and outfall--CRM-115 and CRM-109.
2. Stations downstream from the power plant intake and outfall--CRM-102.7, CRM-100, CRM-94, and CRM-85.

Upstream Stations

Station CRM-115 - This station is located at RM 115, 12 miles upstream from the point of plant discharge. The river is approximately 42 feet (13 meters) deep and 750 feet (230 meters) wide (Figure 11). The right-hand bank (looking upstream) is partially lined with high limestone bluffs with a minimum of overbank area. The left side consists of low banks with a narrow mud shelf before plunging to maximum depth. The right shoreline is rocky and generally overhung with trees, and the left shoreline is studded with stumps and small twigs. There are very few aquatic macrophytes present. Physical, chemical, and biological samples were collected at this station.

Velocity of the river at all of the stations varies considerably due to releases from Cheatham, Barkley, and Kentucky Dams and local inflows.

In 1966 a study (8) using computer-determined canal flows, known local inflows, and turbine releases from Barkley and Cheatham dams was made over a month-long period of varying discharge. The results of this study show that velocities at RM 103.3 varied from approximately 1.3 feet per second (fps) positive flow to a 0.3 fps negative flow. Therefore, velocities are dependent on cross-sectional area of the station and water releases at Barkley, Kentucky, and Cheatham dams. Generally speaking, the river becomes wider as it travels downstream, with a resultant decrease in velocity. Negative flows will not extend upstream to this station.

Station CRM-109 - This station is located 6 miles above the outfall. Under normal conditions, this station will not receive heated water. However, during periods of low water levels when releases from both dams are at a minimum, heated water could conceivably move upstream to this point. The bottom contour is very steep, with a maximum depth of 42 feet (13 meters). The width is about 750 feet (230 meters)(Figure 10). Both sides of the river are low-banked. Again, the left-hand bank has a narrow mud shelf, and the right-hand bank is steep-sided but lacks the rocks of Station CRM-115. There is very little aquatic vegetation present. Physical, chemical, periphyton, plankton, and macrobenthos samples were collected at this station.

Downstream Stations

Station CRM-102.7 - This is the first station below the plant outfall. The river is about 50 feet (15 meters) deep and 1,200 feet (370 meters) wide (Figure 6). The river banks at this station have a variety of topographical features which consist of high limestone bluffs; a low, fairly wide mud bank; shallow mud overbank areas; and steep, rocky shorelines.

Because of the extreme width of the river, the velocity is noticeably less than upstream stations; however, velocity, as stated earlier, is dependent upon dam releases and may become negative at this station during periods of low discharge (8). There is some emergent aquatic herbaceous growth present on the mud flats. All of the parameters were sampled at this station.

Wells Creek, a very productive tributary of the Cumberland River, empties into the river immediately upstream from this station.

Station CRM-100 - This station is located 3 miles downstream from the plant outfall. The river here is about 800 feet (244 meters) wide and 40 feet (12 meters) deep (Figure 5). The river narrows at this point, and velocity increases from Station 102.7. The bottom profile is very steep, with little overbank area on either side. Limestone bluffs line the left-hand bank, and the shoreline is rock. The right-hand bank is low and lined with trees. The shoreline is muddy, with a few stumps and twigs. There is very little aquatic vegetation present. All of the parameters except fish were collected at this station.

Station CRM-94 - This station is located 9 miles below the outfall. The topography is very flat, and the banks are lined with mature hardwoods. Effects of the impoundment are evident, but there is still a moderate current prevailing. Both sides have a narrow overbank area but are cleanly scoured and devoid of aquatic vegetation. The river is about 750 feet (230 meters) wide and 53 feet (16 meters) deep (Figure 3). All parameters except fish were collected from this station.

Station CRM-85 - This station is located at the mouth of Bear Creek 18 miles below the power plant outfall. There are very definite signs of

impoundment influence in evidence here. Although the main channel is still cleanly scoured, Bear Creek and backwater along the river are choked with cattails and other emergent growth. Both banks of the river are very low, and there is an extensive overbank area on the right side. The bottom contour is still very steep, with a maximum depth of 53 feet (16 meters) and a width of about 900 feet (265 meters)(Figure 2). The current is noticeably slower at this station. All physical and chemical parameters were collected here along with periphyton, plankton, and macrobenthos.

In addition to the stations above, temperature and bottom profiles were established for the following stations:

Station CRM-106 - This station is located 3 miles upstream from the outfall.

Stations CRM-103 L and R - The river at this point is divided into a new and an old channel. It is at this point that the plant effluent will empty into the river and into the old channel (CRM-103 R).

Station CRM-97 - This station is located 4 miles below the outfall.

This series of stations was included in order to better document the temperature profile near the plant outfall.

PHYSICAL PARAMETERS

Bottom Contours

To facilitate the characterization of the river throughout the study area, bottom contours were drawn with the use of sonar equipment. These contours were established at RM 115, 109, 106, 103 L and R, 102.7, 100, 97, 94.1, and 85 (Figures 2 through 11). The upper stations are characterized by narrow overbank areas, very steep sides, and a relatively flat bottom. Further downstream the overbank area becomes more extensive, but the banks remain steep. Except for the new channel at RM 103, which has been dredged to 15 feet (4.6 meters), maximum depths range from 40 to 55 feet (12 to 17 meters).

Flow

The Cumberland River in the reaches of this study is regulated by Kentucky and Barkley Dams downstream and Cheatham Dam upstream. For all practical purposes, the river was free-flowing until 1943. Calculated from 20 years of pre-dam data, the 7-day 10-year flow value for the river at Clarksville, Tennessee, (RM 126) was 546 cfs.

Soon after 1943, Cheatham Dam (RM 148.4) was constructed. The gaging station at Clarksville was then eliminated, and a new station was established at Cheatham Dam. The period of record for that station begins in 1954 and extends to the present. The 7-day 10-year low flow calculated at Cheatham Dam utilizing these records is 1,486 cfs. The annual 7-day mean low discharge for the 13 years of record ranges from 1,030 cfs in 1956 to 6,310 cfs in 1961.

There are two major drainages on the Cumberland between Cheatham Dam and the Cumberland Steam Plant site: the Red River, entering at Cumberland

RM 125, and Yellow Creek, entering at Cumberland RM 108. The average discharge for the Red River at RM 25.5 is 1,100 cfs; and for Yellow Creek, 9 miles from its mouth, it is 162 cfs. The average discharge for the Cumberland River at Cheatham Dam during this same period was 21,470 cfs. The combined flows of Red River and Yellow Creek are about 1,300 cfs, which constitutes approximately a 6-per cent increase in flow in the Cumberland River between Cheatham Dam and the Cumberland Steam Power Plant site.

Adding 6 per cent to the 7-day 10-year minimum flow from the 13 years of record at Cheatham Dam would result in a 7-day 10-year minimum flow of approximately 1,600 cfs at the plant site.

When the Cumberland plant is in full operation, it will utilize approximately 4,200 cfs for cooling water. To maintain a flow of 4,200 cfs at the plant site (in which case the plant would be utilizing all of the river flow) would require a discharge of approximately 4,000 cfs at Cheatham Dam (4,000 cfs + .06 X 4,000 cfs = 4,260 cfs). During the 13-year period of record at Cheatham Dam, the 7-day low flow value was less than 4,000 cfs during 6 years; the 14-day was less in 4 years; the 30-day was less in 2 years; and in 1969 the flow was less than 4,000 cfs for 90 consecutive days.

The usable storage behind Cheatham Dam amounts to 19,800 acre feet or 10,000 cfs days of water. During 4 of the 13 years of record at Cheatham Dam, the mean discharge for 7 days was sufficiently low that there would have been no way of maintaining flows near 4,000 cfs even if all the 10,000 cfs storage were available and utilized. It may be possible that this deficit in flow can be compl mented by regulating flow in Barkley Reservoir. If so, it would necessitate a backup of water near the plant

site area, which would develop a completely new set of conditions (flow upstream or no flow). Information is needed concerning the control of adequate flows during such low flow conditions.

Light Penetration

Light penetration into water is exceedingly variable. Factors affecting the penetration, among others, are: suspended solids, microscopic plants and animals, and color. The region in which light penetration is adequate for photosynthesis is often referred to as the trophogenic zone, or that layer that encompases 90 percent of the incident light. Plant physiologists refer to the point where the volume of carbon dioxide being released in respiration is exactly equal to the volume being consumed in photosynthesis as the "compensation point" (3). Myers (2) found the compensation point for a number of aquatic plants to be 1 to 2 percent of the intensity of full midday summer sunlight. Generally speaking, biologists are interested in this 1-percent level which is the point where net productivity ceases.

Light penetration studies were made at two stations, CRM-115 and CRM-102.7, in September 1971 and January 1972. In the September 1971 study, the depth at which 1 percent of the incident light remained at Station CRM-115 was 3.0 meters, and at Station CRM-102.7 it was 2.4 meters (Table 2). In January 1972 the depth of 1 percent light transmission was somewhere between 0.6 and 1.2 meters (Table 3). This reduction in light transmission was due to increased turbidity from surface runoff after heavy rains.

CHEMICAL PARAMETERS

Temperature

Daytime high surface water temperatures ranged from 22.2°C. at Station CRM-109 to 24.0°C. at Station CRM-115 during the September 1971 sampling. During the January 1972 sampling, water temperature was a uniform 9.8°C.

To characterize the preoperational temperature profile in the river throughout the study area, temperatures were taken at the left quarter point, middle, and right quarter point at points through the vertical profile. This was done at river miles 115, 109, 106, 103 L and R, 102.7, 97, 94.1, and 85. Figures 12 through 20 portray the data for the September 1971 sampling period. Generally speaking, the surface temperature depicts the influence of air temperature; however, some of the anomalies, such as shown in Figure 17 for Station CRM-102.7, can be explained as the result of turbulence within the river. In most cases temperature declined with depth; but again, mixing was evident at nearly all stations and was nearly complete at some stations (Figures 16, 18, and 19). This is important to the dissipation of the heated water, since mixing with the cooling water is of much greater importance than the loss of heat to the atmosphere.

During the January 1972 sampling run, temperatures were a constant 9.8°C. throughout the river. This complete mixing was due to vast amounts of runoff water from heavy rains just prior to the sampling run.

Dissolved Oxygen

Because of the important interrelations between water temperature and dissolved oxygen, diel oxygen data were collected for two stations (CRM-102.7 and CRM-109). Samples were collected from the middle and quarter

points on the horizontal plane and just below the surface, middle, and near the bottom on the vertical. The results of the sampling can be seen in Figures 21 through 26.

The Tennessee Valley Authority has dissolved oxygen monitors located at CRM-80, CRM-102.7, and CRM-120. These monitors have been collecting data since July 1970, and a portion of that data has been extracted from STORET and is shown in Table 4.

As can be seen, the two sets of data are comparable. Unfortunately, the sky was overcast during the diel study; and as a result, there was a steady decline in dissolved oxygen concentration throughout the day instead of the increase one would expect. However, of more importance is the fact that the water is less than 50 percent saturated with oxygen for a large part of the day throughout the late summer and early fall months (Table 4). These low dissolved oxygen levels are abnormal and are probably due to Cheatham Dam releases, but their exact cause should be determined. Data also indicate there was a greater drop in dissolved oxygen during the diel cycle at Station CRM-102.7 than at Station CRM-109. This can possible be the result of the introduction of oxygen-demanding constituents in the water from Wells Creek.

Dissolved oxygen concentrations at Station CRM-102.7 occasionally reach lows less than 4 ppm (Table 4). Preoperational maximum water temperature at Station CMR-102.7 was 25.2°C. (78°F.). Estimated rise in temperature at CRM-102.7 due to the steam plant is 10°F. Maximum temperature would then be 30°C. (88°F.), which is approaching maximum temperature for most temperate fishes. Of greater importance, perhaps, is the effect of this rise in temperature on the already low dissolved oxygen concentration.

Dissolved oxygen concentrations during the January 1972 diel study ranged from 10.6 ppm to 11.2 ppm (Table 5).

BIOLOGY

Phytoplankton

The phytoplankton community at the six stations (CRM-115, CRM-109, CRM-102.7, CRM-100, CRM-94, and CRM-85) was dominated by pennate and centric (Melosira varians) diatoms and a few Ankistrodesmus, Scenedesmus, and Oscillatoria species. Except for Ankistrodesmus and Scenedesmus, most of the organisms collected are adventitious planktonic organisms having their origin in the periphytic community.

Total phytoplankton counts were low (Figure 27) and revealed no significant differences among stations at the 0.05 level (Table 6). Appreciable differences may exist among the stations; however, due to excessive variability, those differences remain undetected (Tables 7 and 8).

The dominant algae and scarcity of organisms in our samples indicate this is a "typical" river situation, dominated by periphytic forms and allochthonous phytoplankters probably from upstream impoundments and tributaries.

Periphyton

In contrast to the allochthonous phytoplankton which may be in rivers or streams, the periphyton are true components of the stream biota; and on a particular substrate, reflect the quality of water continuously flowing over them. Therefore, the periphyton community is an excellent water quality indicator for a particular time period. Changes may range from subtle alteration of species composition to extremely dramatic results, such as when a community of predominantly diatom growths is drastically changed by the addition of pollutants which result in growth of extensive slime-forming bacterial colonies.

Diatometer recovery was very successful in September except both diatometers near the left bank were lost at Station CRM-94; therefore, all analyses are from the right bank at this station.

Total periphyton counts revealed no significant differences (Figures 28 and 29, Tables 9 and 10) among stations in September and January.

The total periphyton counts in January were considerably less than those in September. Although the dominant species (Gomphonema olivaceum and Gomphonema parvulum) are cold-water forms, a longer incubation period would have been more desirable during this period.

The nature and severity of stress such as a significant increase in temperature, are not only reflected in standing crop counts, but also in other characteristics such as biomass/chlorophyll a ratios (autotrophic indices). Periphyton communities in relatively unperturbed waters are composed of algae with autotrophic indices similar to those reported for algal cultures (40-96)(6). As the level of stress (significant temperature increases) increases, the algae are replaced by non-chlorophyllous organisms resulting in an increase in the autotrophic index. The data (Figures 30 and 31, Tables 11 and 12) indicate there are no significant differences among the stations in this study. Based on previous studies (6), it is obvious that the community is not entirely composed of algae.

Recent developments in information theory have stimulated ecologists to apply the Shannon-Wiener function to measure species diversity (9), which is an additional tool for measuring stress on community structure. It is based on the generally observed phenomenon that relatively undisturbed environments support communities having large numbers of species with no individual species present in overwhelming abundance.

Mean diatom diversity ($\bar{d}$) showed a significant difference among stations (Table 13). This difference is particularly apparent between Stations CRM-94 and CRM-115, and CRM-94 and CRM-100 in September (Figure 32). The January data revealed no significant differences (Figure 33, Table 14).

In general, "$\bar{d}$" will increase with an increase in total numbers of species, but the function is also influenced by evenness (equitability) with which the individuals are distributed among the species. Although "$\bar{d}$" takes the number of species and equitability into account and reduces them to a common scale, equitability by itself may be more sensitive to the stability of physical and chemical conditions (9). Slight levels of stress will reduce equitability (e) below 0.5 and generally to a range of 0.0 to 0.3. Based on "e", most of our stations (Figures 34 and 35) on the Cumberland appear to be under a slight amount of stress; and the analyses of variance (Table 15) indicate there is a significant difference among stations in September. This difference is attributable to differences in the means at Stations CRM-100 and CRM-94, and CRM-100 and CRM-85. The January data (Table 16) did not reveal any significant differences among stations.

A majority of the dominant diatoms (Stephanodiscus hantzschii, Melosira varians, Navicula graceloides, Microsiphona potomos, and Navicula rhynchocephala) in our September samples are tolerant of slightly brackish waters or waters with a high mineral content (Table 17). There is no information on the tolerance limits of Gomphonema species or Nitzschia bacata, and Melosira distans is widespread throughout the Southeast. Navicula graceloides was the number one or two dominant in all of the replications, and it is supposedly tolerant of slightly brackish waters.

A general examination of the various parameter means suggests there is a general trend of less perturbation or stress at Stations CRM-85, CRM-94, CRM-109, and CRM-115 and a more disturbed situation at Stations CRM-100 and CRM-102.7.

Macroinvertebrates

Major emphasis was placed on the qualitative and quantitative characterization of the macroinvertebrate community at six stations. Because of the contour of the river bottom throughout the study area (steep sides, great depth, and hard clay substrate), benthic sampling was restricted to the shallow, muddy overbank areas on each side of the river. Three Ponar dredge samples were collected from each side of the river at each station (see Appendix A). In addition, qualitative samples were collected from the same areas utilizing dip nets and hand picking substrates such as logs and other debris.

A total of 950 organisms, belonging to 24 families, were collected in the quantitative sampling. Standing crops were generally low, with numbers of individuals and taxa varying from station to station, with no apparent relationship to position within the study area (Tables 18 and 19). The maximum number of individuals (a total of 232 from six Ponar samplers) was collected from Station CRM-100, which is located approximately midway in the study area. The fewest number (a total of 77 from six Ponar samplers) was collected from the uppermost station (CRM-115). The uppermost station also produced the fewest number of taxa, while the maximum number of taxa were collected from Station CRM-94. Quantitatively, the Tubificidae dominated all stations; and qualitatively, the Chironomidae dominated all stations (Tables 20-A and 20-B).

The mean diversity of organisms at the six stations, utilizing the Shannon-Weiner function, ranged from 2.2 to 3.5 (Table 21). Stations CRM-109 and CRM-85 were within the 3 to 4 range, which Wilhm (4) found to be indicative of unpolluted waters. The "$\bar{d}$" values for the remaining four stations ranged from just below 3 (2.9 for Stations CRM-102.7 and CRM-94), down to 2.2 for Station CRM-115.

According to Tebo (personal communication), equitability levels below 0.5 have not been encountered in Southeastern streams known to be unaffected by oxygen-demanding waters. In such streams, "e" usually ranges between 0.6 and 0.8. Stations CRM-109, CRM-102.7, and CRM-85 "e" values are in this range; but the reaminder of the stations drop to 0.4. The upper station, CRM-115, is located approxiamtely 30 miles downstream from Cheatham Dam and 10 miles downstream from Clarksville, Tennessee. This would tend to reduce dissolved oxygen concentrations in the upper portions of the study area, which accounts for the reduced "e" value at Station CRM-115. Wells Creek, an organically rich tributary of the Cumberland River, enters at RM 102.8. The station immediately downstream (CRM-102.7) does not show the effects of this tributary, but both CRM-100 and CRM-94 show a considerable reduction in "e" value (Table 21). Diversity values show the greatest reduction (2.4) at Station CRM-100 and then begins to recover at CRM-94, which has a "$\bar{d}$" value of 2.9, and then increases to 3.5 at CRM-85.

The qualitative data indicates a similar diversity pattern with Chironomids and Tubificids dominating, and a scattering of other taxa making up the remainder of the population (Table 22). Various authors have classified invertebrates according to their tolerance to organic water. In an unpublished EPA manual, the classifications of such authors have been

arbitrarily placed in three categories--tolerant, facultative, and intolerant --and the data placed into tabular form. These categories are defined as follows:

1. Tolerant - Organisms frequently associated with gross organic contamination and generally capable of thriving under anaerobic conditions.
2. Facultative - Organisms having a wide range of tolerance and frequently associated with moderate levels of organic contamination.
3. Intolerant - Organisms that have not been found associated with even moderate levels of organic contaminants and are generally intolerant of even moderate reductions in dissolved oxygen.

The only organisms collected from the Cumberland River which, on the basis of the data of numerous authors, would be classified s intolerant included the caddisfly, Hydroptila sp.; the mayfly, Stenonema proxium; the clam, Proptera alata; and the Chironomids Nanocladius alterantherae, Xenochironomis xenolabis, Stenochironomis sp., and Tribelos jucundus. All other organisms have been classified as facultative or tolerant. It is quite significant that six of the seven intolerant species collected were found at only the uppermost station. Since the presence or absence of a species may be more dependent on characteristics of the environment than on the effects of pollution, it is possible that these species were absent from downstream stations because of the influence of water impoundment by Barkley Dam on the lower stations.

Branchiura sowerbyi, a tubificid, is considered intolerant to organic pollution and was considered a good warm-water indicator species, since it was thought to be restricted to warm-water effluents. However, records now show it appearing in cold-water sites. Specimens found at such sites

tend to be much smaller than those found at warm-water sites; and as a result, its size is now thought to be important in relation to its presence (1). Branchiura sowerbyi was found at each station in the preoperational sample, and it will be interesting to note whether there will be significant differences in its size-location relationship in regard to the warm-water effluent from the power plant.

Fish

Fish were collected quantitatively with a fish shocker by collecting for half-hour periods at similar stretches of the river. Station CRM-115 was selected for the station unaffected by the power plant, and Station CRM-102.7 was selected as the experimental station. There were two definite habitats at each station: bluffs lining the river with steep, rocky shoreline; and flat, muddy, stump- and twig studded shoreline. Sampling consisted of three half-hour units of shocker effort in each habitat at each station both day and night. The results of this sampling are given in Tables 23 through 28. A total of 32 species of fish, representing 10 families were collected during the two sampling periods (Table 29). The lower station (CRM-102.7) produced both a greater biomass and total number of fish during each of the sampling periods. Although the January sampling produced considerably less biomass and fewer fish than did the September sampling, species composition was quite similar (Tables 30 and 31).

To facilitate comparison, fish can be grouped into arbitrary categories based on some characteristic, such as feeding or habitat preference. In this study they have been divided into six categories based on food and feeding habits as described by Tebo (5). They are as follows:

1. Group I - Large, sight-feeding carnivores that feed on other fish.
2. Group II - Species that feed primarily on insects.
3. Group III - Species that feed primarily on plankton and algae.
4. Group IV - Species that feed primarily on mollusks.
5. Group V - Omnivors that feed indiscriminately on plant and animal matter from the bottom.
6. Group VI - Scavengers that take any available food and are primarily bottom feeders. Some of these species may sometimes act as predators. The group also includes many important food fish and species that are tolerant of degraded conditions.

Tables 30 and 31 depict species composition at the two stations during the two sampling periods. As would be expected, Group II, which includes many of the forage fish, produced the largest number of species and individuals and except for the January 1972 sample at Station CRM-102.7, also produced the greatest biomass. All groups were represented at Station CRM-115 in the September sampling, but representatives from Group V were missing at Station CRM-102.7 in September and from both stations in the January sampling. This group includes the suckers, which represented less than 1 percent of the total number and weight at the one station from which they were collected. This probably reflects the habitat preference of this group of fish, which is generally fast, clear, rock-strewn streams.

Cumberland River fish show a definite preference for the rocky habitat as opposed to the stump-infested one. This is documented in Table 32, which shows that rocky habitats produced the greatest biomass in seven out of eight occasions, the most individuals in six out of eight, and the most species in five out of eight occasions.

Night sampling versus day sampling data (Tables 15 through 20) reveal no particular trends as far as biomass, total number of individuals, or total number of species are concerned. Species composition in the September sampling, however, reveal that during the day, forage fish (Groups II and III) are present along the shore, while most of the predators are lying in the deep offshore water (Table 33). At night the predators (Group I) are in abundance, and the forage fish are more poorly represented. In the January sampling, however, these expected results did not develop. This, too, is probably due to the high water and excessive turbidity, which influenced the effectiveness of the sampling gear and, quite logically, the location of fish.

The overall results from the two stations indicate that a considerably larger standing crop is present at the lower station (CRM-102.7)(Table 34). The total number of fish is 105 percent greater at Station CRM-102.7 than at Station CRM-115, and the total weight is 40 percent greater at Station CRM-102.7 than at Station CRM-115 in the September sampling. In the January sampling, the total number of fish was 79 percent greater and total weight 179 percent greater at Station CRM-102.7 than at Station CRM-115. This greater standing crop is probably due to the influence of Wells Creek which empties into the Cumberland River immediately upstream from Station CRM-102.7.

According to TVA biologists (personal contact), Wells Creek is a very productive tributary where fish concentrate to feed and spawn. It is very probable that warm water will move upstream into Wells Creek when the power plant begins generating, which may have a detrimental effect on the spawning of Cumberland River fish.

DISCUSSION

The phytoplankton standing crop in this section of the Cumberland River was dominated by adventitious forms of diatoms originating from the periphytic community. Although differences were not statistically significant, the mean counts were somewhat higher at Stations CRM-100 and CRM-102.7 immediately below the confluence of Wells Creek.

Periphyton counts and autotrophic indices were similar to the phytoplankton in that no significant differences were observed among stations. Although differences were not statistically significant, the mean counts were somewhat higher at stations CRM-102.7 and CRM-100. The higher algal populations subsequently reduce the autotrophic index; therefore, the mean autotrophic indices tend to be lower at Stations CRM-102.7 and CRM-100 in September.

The more sensitive community indices in September, such as mean diversity and equitability, indicate there are significant differences among stations, and the means tend to be lower at CRM-102.7 and CRM-100, which one would expect with higher population counts at these two stations.

The macroinvertebrate standing crop was quite low, dominated quantitatively by oligochaets and qualitatively by chironomids. Population density and diversity varied from station to station with some indication of reaction to enrichment at stations below Wells Creek.

The fish community reflects a "healthy" aquatic environment with forage fish in abundance, adequate numbers of predators present, with the remaining groups present in sufficient numbers. While both stations supported diverse communities of fish, the lower station (CRM-102.7) produced considerably more fish and greater biomass, again suggesting a significant influence from Wells Creek.

Taking all parameters into consideration, the Cumberland River between RM 115 and 85 can be characterized as a relatively "healthy" stream, supporting abundant and diverse communities of plankton, periphyton, macroinvertebrates, and fish but showing slight signs of stress due to high mineral sources and oxygen-demanding substances from upstream and from tributaries within the study area.

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PARTICIPANTS

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3. Dr. Todd Harris, Biologist
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5. Mr. William Peltier, Aquatic Biologist
6. Mr. Donald Schultz, Aquatic Biologist
7. Mr. David Smith, Biologist
8. Mr. Ronald Weldon, Aquatic Biologist
9. Mr. William Woodall, Biologist

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Table 1

TENNESSEE VALLEY AUTHORITY

RIVER CONTROL BRANCH

CHEATHAM DAM

DISCHARGE IN DAY-SECOND-FEET

1970

DAY	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER	TURBINE	OTHER
1	[illegible]	118,592	21,318	300	23,580	300	22,230	300	19,650	56,190	5,520	670	13,980	300	16,230	300	13,340	2,410	9,330	300	9,910	300	6,120	300
2	0	101,940	23,538	1,150	16,600	300	11,590	99,500	16,950	46,680	3,030	300	10,020	300	18,880	300	14,040	1,210	3,440	300	9,060	300	2,810	300
3	0	79,630	24,340	3,200	15,050	690	0	99,600	0	77,310	6,600	300	23,420	300	18,340	300	14,540	300	4,520	300	12,520	300	2,660	300
4	23 760	53,910	23,210	9,600	22,210	300	0	89,040	0,860	90,380	6,140	300	22,090	300	19,020	300	14,540	300	4,520	300	12,290	300	2,660	300
5	23 610	42,950	24,070	15,360	23,030	300	14,470	49,710	22,060	19,390	8,610	300	23,150	300	19,090	300	12,340	300	4,510	300	12,290	300	2,660	300
6	22 550	25,030	23,695	16,350	24,190	3,780	22,360	39,660	21,950	12,970	8,690	300	20,790	300	20,890	300	2,910	300	6,660	300	9,880	300	3,370	300
7	23 620	16,490	24,250	9,950	24,830	3,600	22,980	29,220	23,390	2,200	7,020	300	9,980	300	18,630	300	3,490	330	5,610	300	11,280	300	4,130	300
8	23 720	11,240	24,650	13,870	22,990	870	23,180	6,100	23,310	3,200	10,030	300	5,990	300	19,000	300	3,410	300	6,630	300	8,240	300	4,130	300
9	24 270	9,960	22,220	26,610	21,170	1,690	23,320	3,850	23,750	3,200	6,990	300	13,520	300	22,190	300	3,440	300	7,930	300	9,680	300	4,560	300
10	24 570	16,160	23,900	20,940	22,250	330	25,260	1,040	24,760	6,990	6,590	300	16,930	300	19,230	300	9,610	300	9,760	300	6,250	300	4,290	300
11	24 230	18,760	23,960	12,360	21,630	300	24,270	300	22,760	19,890	11,670	300	15,040	300	9,350	1,000	13,360	300	9,780	300	11,940	300	9,890	300
12	24 090	18,510	24,760	2,570	24,060	300	18,970	300	21,080	29,870	17,270	300	11,660	300	18,420	300	7,910	300	6,490	300	13,210	300	10,270	300
13	24 060	1,590	21,830	2,150	23,620	330	16,970	390	21,610	30,990	16,790	300	14,690	3,830	13,910	300	9,060	300	9,670	300	13,660	300	13,340	300
14	23 110	1,610	23,060	2,110	23,620	2,130	16,110	750	21,620	29,920	14,810	330	15,570	1,630	13,690	300	9,760	300	11,750	300	14,730	3,090	13,740	670
15	24 970	6,540	23,760	27,660	24,190	2,910	22,220	330	22,290	6,510	11,890	300	15,200	2,690	6,960	300	13,760	300	13,690	300	14,550	3,090	15,190	2,110
16	24 860	4,610	19,950	49,700	24,730	6,830	21,690	330	22,870	3,200	7,370	300	15,670	7,920	14,160	300	14,790	9,000	11,870	300	13,520	300	13,150	300
17	25 930	330	20,610	39,720	25,960	3,190	22,930	330	23,160	6,160	6,450	300	19,360	2,740	14,210	300	15,870	6,700	11,450	300	13,560	300	13,290	300
18	25 860	330	20,950	31,370	23,760	2,900	23,260	330	21,730	420	8,560	300	18,160	300	16,060	300	15,490	9,760	9,990	300	13,460	300	15,970	350
19	27 620	330	22,310	17,620	24,610	3,170	24,720	330	5,770	1,090	13,500	300	18,960	300	14,110	300	15,440	13,360	8,570	300	12,620	300	13,830	300
20	27 770	300	22,680	18,820	24,400	2,250	25,350	4,230	10,300	300	9,310	300	15,200	300	9,120	300	15,660	9,090	6,710	330	12,180	350	8,740	350
21	27 810	300	22,350	17,350	24,670	5,600	25,210	12,440	14,440	300	24,020	27,210	4,220	1,510	12,030	300	15,300	9,270	9,010	300	13,440	300	28,430	12,390
22	25 910	870	21,560	22,500	23,940	2,170	24,730	11,750	18,950	2,110	20,400	41,160	7,370	300	14,290	300	14,190	300	6,630	300	13,090	690	19,260	22,910
23	24 330	6,160	21,290	13,760	24,660	2,630	23,220	2,510	19,130	330	21,750	19,310	6,520	300	10,960	300	14,090	720	5,080	300	13,920	1,330	19,330	29,260
24	24 920	6,310	22,590	6,160	25,120	4,990	23,770	29,660	17,520	300	21,120	4,220	12,220	300	10,810	300	14,760	4,820	3,530	300	13,810	4,710	20,570	23,710
25	25 960	2,150	22,890	300	25,040	2,630	22,560	47,510	17,160	300	12,920	300	6,760	300	8,930	300	14,140	300	5,310	310	14,710	5,080	22,650	3,660
26	27 260	300	23,020	1,830	24,360	2,640	19,600	41,240	16,960	300	7,960	300	3,550	300	2,950	300	12,170	300	3,950	300	15,560	8,050	21,720	300
27	5 610	660	23,030	6,170	28,900	360	20,050	35,280	14,670	300	16,050	300	15,210	300	9,150	300	9,890	300	5,550	300	14,630	8,020	22,250	300
28	7 490	300	22,950	13,960	23,730	300	20,360	42,600	13,890	300	18,730	300	15,520	300	11,600	300	9,950	300	5,550	300	11,320	300	19,530	300
29	7 900	300			22,220	300	20,040	37,490	16,760	330	3,580	750	15,390	300	12,130	300	6,810	300	6,990	300	6,410	300	15,350	300
30	19 850	300			20,290	300	20,460	34,930	7,600	300	18,860	990	16,180	300	14,600	420	9,920	300	13,260	300	9,220	300	20,060	300
31	21,390	300			22,520	300			2,580	330			13,670	300	19,230	3,200			11,480	300			21,030	300
TOTAL	585,700	540,730	660,150	383,650	732,700	58,450	605,120	659,350	536,090	372,270	334,890	200,940	410,250	27,020	429,990	23,020	326,200	95,800	219,410	9,310	341,510	56,000	390,190	117,060
AVERAGE	18,910	18,040	22,060	12,380	23,630	1,880	20,170	21,270	17,290	12,010	11,160	6,700	13,230	870	13,740	420	10,940	3,060	7,080	300	11,380	1,870	12,770	3,910

1969-1970 WATER YEAR DISCHARGE

	TOTAL	AVERAGE
TURBINE	9,336,360	14,620
OTHER	2,499,640	6,832
COMBINED	7,810,080	21,452

OTHER DISCHARGE IS ESTIMATED LEAKAGE OR GATE DISCHARGE PLUS ESTIMATED LEAKAGE.
U.S. ARMY, CORPS OF ENGINEERS PROJECT.

1970 ANNUAL DISCHARGE

	TOTAL	AVERAGE
TURBINE	5,529,960	15,151
OTHER	2,369,760	6,492
COMBINED	7,899,720	21,633

PLATE 102

Table 2

PERCENT LIGHT TRANSMISSION AT TWO STATIONS ON THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - SEPTEMBER 1971

Depth (m)	Percent Transmission Stations	
	CRM-115	CRM-102.7
Surface*	84	82
0.6	41	26
1.2	18	9
1.8	8	3
2.4	3	1
3.0	1	0.4
3.6	0.5	0.2
4.2	0.3	0.07
4.8	0.1	0.01
5.4	0.06	<0.01
6.0	0.03	0 **
6.6	0.01	
7.2	<0.01**	

* 3" to 6" below water surface

** Bottom

Table 3

PERCENT LIGHT TRANSMISSION AT TWO STATIONS ON THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - JANUARY 1972

Depth (m)	Percent Transmission Stations	
	CRM-115	CRM-102.7
Surface*	80	86
0.6	9	7
1.2	0.6	0.28
1.8	0.02	0.02
2.4	<0.01	<0.01
3.0	0	<0.01
3.6		<0.01
4.2		<0.01

* 3" to 6" below water surface.

Table 4

TEMPERATURE, DISSOLVED OXYGEN IN PPM, AND PERCENT SATURATION FROM THREE STATIONS ON THE CUMBERLAND RIVER[1]

Date	Station								
	CRM-80			CRM-102.7			CRM-120		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
7-15-70									
T	26.5	25.7	25.6	24.9	24.2	24.1	23.9	23.7	23.7
DO	4.3	3.8	3.5	5.4	5.0	4.9	5.7	5.5	5.5
%S	53	46	43	64	59	58	67	65	65
8-19-70									
T	25.3	24.9	24.9	24.1	24.0	24.0	22.9	22.7	22.7
DO	4.8	4.6	4.5	5.2	5.0	5.0	5.5	5.5	5.3
%S	57	55	54	61	59	59	63	63	63
9-24-70									
T	24.7	24.7	24.7	24.9	24.9	24.9	24.6	24.6	24.5
DO	4.9	4.9	4.7	4.8	5.1	5.0	5.8	5.6	5.5
%S	58	58	56	57	61	60	69	67	65
10-7-70									
T	21.0	21.0	21.0	10.7	20.7	20.7	19.8	19.8	19.8
DO	5.5	5.5	5.8	5.3	5.2	5.1	5.2	5.3	5.1
%S	61	61	64	59	58	57	57	58	55
2-4-71									
T	5.8	5.8	5.8	5.5	5.5	5.5	5.2	5.2	5.2
DO	11.5	11.7	11.6	11.9	12.2	11.9	12.2	12.2	12.1
%S	92	94	93	95	98	95	95	95	95
3-2-71									
T	9.2	9.2	9.2	9.5	9.5	9.5	9.1	9.1	9.1
DO	11.4	11.4	11.4	11.7	11.7	11.7	11.7	11.7	11.7
%S	98	98	98	104	104	104	104	104	104
4-8-71									
T	10.7	10.6	10.6	10.7	10.5	10.5	10.6	10.6	10.6
DO	10.7	10.5	10.5	11.0	10.7	10.7	10.9	10.7	10.8
%S	96	96	96	99	95	95	98	96	97
4-27-71									
T	16.6	16.6	16.6	16.8	16.2	16.2	16.2	16.2	16.1
DO	9.0	8.8	8.9	10.0	9.0	8.5	8.5	8.5	8.7
%S	93	91	92	103	90	85	85	85	87
6-2-71									
T	17.5	17.0	17.0	18.9	16.8	16.7	16.9	16.7	16.7
DO	8.4	8.2	8.4	9.2	8.8	8.7	9.2	8.7	9.1
%S	88	85	87	98	91	90	95	90	94
7-15-71									
T	25.7	25.8	25.9	24.9	25.2	25.2	24.7	24.8	24.8
DO	4.2	4.0	4.2	3.8	3.7	3.5	3.6	3.8	3.6
%S	51	49	51	45	44	42	43	45	43

[1] TVA data from STORET

Table 5

DISSOLVED OXYGEN DATA FOR TWO STATIONS ON
THE CUMBERLAND RIVER - JANUARY 1972

Time	Depth	Temp.	Dissolved Oxygen in P.P.M.					
			Station					
			102.7			109.0		
			Right	Middle	Left	Right	Middle	Left
0600	S	10°C	10.8	10.9	11.1			
0600	M	10°C	10.8	11.0	11.0			
0600	B	10°C	11.1	10.8	10.9			
1100	S	10°C	11.0	11.0	11.0			
1100	M	10°C	11.2	11.1	11.0			
1100	B	10°C	11.0	11.0	11.0			
1800	S	10°C	11.0	11.0	11.0			
1800	M	10°C	11.0	11.1	11.1			
1800	B	10°C	10.9	11.0	11.0			
0700	S	10°C				10.9	10.9	10.9
0700	M	10°C				10.9	10.9	11.0
0700	B	10°C				11.0	10.8	10.6
1200	S	10°C				11.0	11.0	11.0
1200	M	10°C				11.0	11.0	11.0
1200	B	10°C				11.0	11.0	10.9
1730	S	10°C				11.0	11.0	10.9
1730	M	10°C				11.0	11.0	11.1
1730	B	10°C				11.0	11.0	10.8

S - Surface, M - Middle, B - Bottom

Table 6

ANOVA[1] FOR TOTAL PHYTOPLANKTON COUNTS
SEPTEMBER 1971

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	25,231	25,231	
Among treatments	5	1,620	324	2.33
Experimental error	120	16,706	139	
Total	126	43,557		

F = 2.67

[1] ANOVA - Analysis of variance for completely randomized design with one observation per experimental unit.

Table 7

MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIATION FOR THE PLANKTON AND PERIPHYTON ANALYSIS CUMBERLAND RIVER, TENNESSEE - SEPTEMBER 1971

Parameters	Station								
	CRM-115			CRM-109			CRM-102.7		
	$\bar{Y}$	s	C.V.	$\bar{Y}$	s	C.V.	$\bar{Y}$	s	C.V.
Phytoplankton counts(#/ml)	13.0	8.0	0.62	10.0	8.0	0.80	16.0	13.0	0.81
Periphyton counts(#/mm^2)	136.0	54.0	0.40	156.0	50.0	0.32	182.0	60.0	0.33
Biomass(g/m^2)	10.01	3.69	0.40	7.39	0.58	0.08	10.44	2.66	0.26
Chlorophyll a(g/m^2)	0.61	0.04	0.66	0.048	0.01	0.21	0.081	0.04	0.49
Autotrophic index	176.22	40.04	0.23	165.64	55.62	0.34	139.08	34.14	0.24
Mean diversity	2.9556	0.3462	0.12	3.1778	0.4430	0.08	2.9074	0.7175	0.25
Equitability	0.4001	0.0798	0.20	0.4633	0.1120	0.24	0.3772	0.1307	0.35

Parameters	Station								
	CRM-100			CRM-94			CRM-85		
	$\bar{Y}$	s	C.V.	$\bar{Y}$	s	C.V.	$\bar{Y}$	s	C.V.
Phytoplankton counts(#/ml)	20.0	12.0	0.60	16.0	18.0	1.12	10.0	7.0	0.70
Periphyton counts(#/mm^2)	207.0	52.0	0.25	162.0	43.0	0.26	145.0	29.0	0.20
Biomass(g/m^2)	9.66	2.41	0.25	10.72	1.00	0.09	7.80	1.17	0.15
Chlorophyll a(g/m^2)	0.078	0.01	0.13	0.075	0.03	0.40	0.058	0.02	0.34
Autotrophic indes	126.44	32.98	0.26	143.30	21.96	0.15	136.35	14.00	0.10
Mean diversity	2.5108	0.7334	0.29	3.7135	0.3438	0.09	3.5097	0.4649	0.13
Equitability	0.3068	0.1168	0.38	0.5854	0.1480	0.25	0.4814	0.1159	0.24

$\bar{Y}$ - mean, s - standard deviation, C.V. - coefficient of variation

Table 8

MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIATION
FOR THE PLANKTON AND PERIPHYTON ANALYSIS
CUMBERLAND RIVER, TENNESSEE - JANUARY 1972

Parameters	Station					
	CRM-115			CRM-102.7		
	$\bar{Y}$	s	C.V.	$\bar{Y}$	s	C.V.
Phytoplankton counts (#/ml)	----	----	----	----	----	----
Periphyton counts (#/mm^2)	51.0	8.0	0.16	40.0	2.0	0.05
Biomass (g/m^2)	1.40	0.63	0.45	1.28	0.10	0.08
Chlorophyll a (g/m^2)	0.0050	0.0017	0.34	0.0062	0.0017	0.28
Autotrophic index	321.08	125.83	0.39	205.63	19.97	0.10
Mean diversity	3.0828	0.7348	0.24	2.4775	0.2338	0.09
Equitability	0.3858	0.1914	0.50	0.3051	0.0656	0.21

Table 9

ANOVA FOR TOTAL PERIPHYTON COUNTS
SEPTEMBER 1971

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	1,197,900	1,197,900	
Among treatments	5	27,208	5,442	2.23
Experimental error	38	92,760	2,441	
Total	44	1,317,868		

F = 2.93

Table 10

ANOVA FOR TOTAL PERIPHYTON COUNTS
JANUARY 1972

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	16,471	16,471	
Among treatments	1	276	276	7.67
Experimental error	6	216	36	
Total	8	16,963		

F = 8.81

Table 11

ANOVA FOR AUTOTROPHIC INDEX
SEPTEMBER 1971

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	916,262	916,262	
Among treatments	5	13,566	2,713	1.98
Experimental error	36	49,388	1,372	
Total	42	979,216		

F = 2.95

Table 12

ANOVA FOR AUTOTROPHIC INDEX
JANUARY 1972

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	554,836	554,836	
Among treatments	1	26,576	26,576	3.27
Experimental error	6	48,777	8,129	
Total	8	630,189		

F = 7.67

Table 13

ANOVA FOR PERIPHYTON DIATOM MEAN DIVERSITY ($\bar{d}$)
SEPTEMBER 1971

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	416.3194	416.3194	
Among treatments	5	6.1119	1.2224	4.0571*
Experimental error	38	11.4491	0.3013	
Total	44	433.8804		

F = 2.93 * Significant at 0.05 level

Table 14

ANOVA FOR PERIPHYTON DIATOM MEAN DIVERSITY ($\bar{d}$)
JANUARY 1972

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	61.8322	61.8322	
Among treatments	1	0.7327	0.7327	2.46
Experimental error	6	1.7838	0.2973	
Total	8	64.3487		

F = 8.81

Table 15

ANOVA FOR PERIPHYTON DIATOM EQUITABILITY (e)
SEPTEMBER 1971

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	7.8383	7.8383	
Among treatments	5	0.2749	0.0550	7.050*
Experimental error	38	0.2957	0.0078	
Total	44	8.4089		

F = 2.93 * Significant at 0.05 level

Table 16

ANOVA FOR PERIPHYTON DIATOM EQUITABILITY (e)
JANUARY 1972

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio
Mean	1	0.9548	0.9548	
Among treatments	1	0.0131	0.0131	0.639
Experimental error	6	0.1228	0.0205	
Total	8	1.0907		

F = 7.67

Table 17

DIATOM ASSOCIATIONS[1] IN THE CUMBERLAND RIVER - SEPTEMBER 1971

| Species | Station | | |

Table 18

TOTAL NUMBER, MEAN, AND STANDARD DEVIATION OF BENTHIC TAXA COLLECTED FROM SIX STATIONS ON THE CUMBERLAND RIVER - SEPTEMBER 1971

	Station					
	Above Outfall		Below Outfall			
	CRM-115	CRM-109	CRM-102.7	CRM-100	CRM-94	CRM-85
Total	18	23	15	20	28	24
$\bar{Y}$	4.3	8.2	6.3	7.0	8.3	8.0
s	1.8	4.6	2.1	2.1	2.9	4.9
n	6	6	6	6	6	6

$\bar{Y}$ - mean, s - standard deviation, n - number of samples

Table 19

TOTAL NUMBER, MEAN, AND STANDARD DEVIATION OF BENTHIC ORGANISMS COLLECTED FROM SIX STATIONS ON THE CUMBERLAND RIVER - SEPTEMBER 1971

	Station					
	Above Outfall		Below Outfall			
	CRM-115	CRM-109	CRM-102.7	CRM-100	CRM-94	CRM-85
Total	77	217	107	232	166	168
$\bar{Y}$	12.8	36.2	15.0	38.7	27.7	28.0
s	7.4	31.8	6.1	34.7	13.0	27.7
n	6	6	6	6	6	6

$\bar{Y}$ - mean, s - standard deviation, n - number of samples

Table 20-A

ORGANISMS COLLECTED WITH A PONAR DREDGE FROM THREE STATIONS OF THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - SEPTEMBER 1971

Taxa	Stations																			
	CRM-115							CRM-109							CRM-102.7					
	Sample Number							Sample Number							Sample Number					
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
Coelenterata																					
Cordylophora lacustris										P	P			P							
Spongillidae																					
Spongilla sp.										P	P			P							
Urnatellidae																					
Urnatella gracilis											P			P			P				P
Lophopodidae																					
Lophopodella carteri					P		P														
Pectinatella sp.																					
Plumatellidae																					
Plumatella repens			P				P														
Nematoda (und. sp.)			2				2														
Lumbriculidae																					
Naididae								8	8		2			18			3				3
Nais pardalis																					
Pristina sp.																					
Tubificidae	2	17	1		12	12	44	24	18	1	3	6	5	57	5	5	5	4	6	5	30
Branchiura sowerbyi					3		3	2	2		2	1	1	8		8	1			2	11
Limnodrilus cervix	3		5		1	2	11									1	1		1	5	8
L. hoffmeisteri									3					3				1			1
L. profundicola		1					1	2						2							
Hirudinea (und. sp.)								1						1							
Hydracarina (und. sp.)											1			1							
Ephemeridae																					
Hexagenia sp.		1					1														
Heptageniidae																					
Stenonema proximum																					

P - Present

Table 20-A
(Continued)

Taxa	Stations																							
	CRM-115							CRM-109							CRM-102.7									
	Sample Number							Sample Number							Sample Number									
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total			
Saldidae																								
Saldula sp.																								
Hydroptilidae																								
Hydroptila sp.								1	1	2			1C	4&C		1C					C			
Psychomyiidae																								
Cyrnellus fraternus			2	2			4	8	2	21				31										
Culicidae																								
Chaoborus sp.					2A		2													33	33			
Ceratopogonidae																								
Palpomyia sp.																1A		1A			2			
Sciaridae																								
Tabanidae																								
Muscidae																								
Chironomidae																								
Ablabesmyia janta	1						1																	
A. mallochi											1			1			1				1			
Procladius culiciformis																								
P. (adumbratus)		1					1				1			1	2	1	1				4			
Coelotanypus concinnus																								
Tanypus sp.								1		1				2			1				1			
Nanocladius alternantherae								1			3			4	2		3				5			
Cricotopus sp. 2 Roback		1					1	1																
Chironomus attenuatus					1		1	46		2		16		64										
Xenochironomus festivus								2		1				3										
X. rogersi											1			1										
X. xenolabis																								
Stenochironomus sp.					2		2				4		1	5	1	1	1				3			
Cryptochironomus fulvus											1			1					1		1			
C. ponderosus																								
C. sp. 4 Roback																								
C. sp.																								

C - Case, A - Adult, E - Exuvia

Table 20-A
(Continued)

Taxa	Stations																			
	CRM-115							CRM-109							CRM-102.7					
	Sample Number							Sample Number							Sample Number					
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
Chironomidae																					
Tribelos jucundus																					
Dicrotendipes modestus																					
D. nervosus								1		5				6							
D. neomodestus																					
Microchironomus sp.																					
Polypedilum illinoense																					
P. halterale								1			3			4					1	2	3
Harnischia boydi																					
Tanytarsus sp. 5 Roback																					
Atanytarsus sp.																					
Kneotanytarsus exiguus				1			1														
Corbiculidae																					
Corbicula manilensis	1						1													1	
Unionidae																					
Proptera sp.						1	1														
Total Number of Taxa	4	5	5	2	7	3	18	13	6	8	14	3	4	23	4	7	9	3	4	6	17
Total Number of Individuals	7	21	10	3	21	15	77	98	34	33	22	23	7	217	10	17	18	6	9	48	107

Table 20-B

ORGANISMS COLLECTED WITH A PONAR DREDGE FROM THREE STATIONS OF THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - SEPTEMBER 1971

Taxa	Stations																			
	CRM-100							CRM-94							CRM-85						
	Sample Number							Sample Number							Sample Number						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
Coelenterata																					
Cordylophora lacustris																					
Spongillidae																					
Spongilla sp.																					
Urnatellidae								P						P							
Urnatella gracilis																					
Lophopodidae																					
Lophopodella carteri	P					P	P	P			P			P		P					P
Pectinatella sp.		P					P								P						P
Plumatellidae																					
Plumatella repens	P						P				P	P		P							
Nematoda (und. sp.)				1			1														
Lumbriculidae													1	1					1	3	4
Naididae																				3	3
Nais pardalis																				1	1
Pristina sp.																					
Tubificidae	23	3	5	5	20	32	88	20	2	3	22	7	3	57	5	1	5		12	20	43
Branchiura sowerbyi		1	2	1	1	32	37		2			3	2	7	1	3			13	7	24
Limnodrilus cervix	6		3	2	3		14			1	2		5	8		1			2		3
L. hoffmeisteri					2		2						1	1							
L. profundicola				1	1		2														
Hirudinea (und. sp.)																					
Hydracarina (und. sp.)																					
Ephemeridae																					
Hexagenia sp.																					
Heptageniidae																					
Stenonema proximum	1						1														

P - Present

Table 20-B
(Continued)

Taxa	Stations																				
	CRM-100							CRM-94							CRM-85						
	Sample Number							Sample Number							Sample Number						
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
Saldidae																					
Saldula sp.																					
Hydroptilidae																					
Hydroptila sp.				1			1	1C						C		1				4C	1&C
Psychomyiidae																					
Cyrnellus fraternus									1					1							
Culicidae																					
Chaoborus sp.																					
Ceratopogonidae																					
Palpomyia sp.										1			1	2							
Sciaridae																					
Tabanidae																1E					1
Muscidae											1			1							
Chironomidae																					
Ablabesmyia janta									1					1		1	1				2
A. mallochi									1					1							
Procladius culiciformis		1					1				6		1	7							
P. (adumbratus)											1			1							
Coelotanypus concinnus		4					4		4	6	9	3	21	43	1		2		1		4
Tanypus sp.											1			1							
Nanocladius alternantherae				1			1														
Cricotopus sp. 2 Roback																					
Chironomus attenuatus	1	2		1	25	37	66			1	1	17	2	21		2			6	1	9
Xenochironomus festivus																3	2				5
X. rogersi																					
X. xenolabis																					
Stenochironomus sp.																					
Cryptochironomus fulvus	1	3	2	1		1	8	1				1	2		2						2
C. ponderosus											1		1						1	1	2
C. sp. 4 Roback																					
C. sp.			1				1														

C - Case, E - Exuvia

Table 20-B
(Continued)

Taxa	Stations																						
	CRM-100							CRM-94							CRM-85								
	Sample Number							Sample Number							Sample Number								
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total		
Chironomidae																							
Tribelos jucundus									1					1									
Dicrotendipes modestus																	1				1		
D. nervosus				1			1		2					2			1				1		
D. neomodestus																2			2		4		
Microchironomus sp.										1			1	2					3	2	5		
Polypedilum illinoense	1						1		1					1									
P. halterale	3						3					1		1					13	21	34		
Harnischia boydi													1	1									
Tanytarsus sp. 5 Roback																			1	4	5		
Atanytarsus sp.																			2	4	6		
Rheotanytarsus exiguus																							
Corbiculidae																							
Corbicula manilensis													1	1	2	5				1	8		
Unionidae																							
Proptera sp.																							
Total Number of Taxa	9	7	5	10	6	5	20	5	9	6	10	7	13	28	6	11	6	0	12	13	24		
Total Number of Individuals	36	14	13	15	52	102	232	22	15	13	43	32	41	166	11	20	12	0	57	68	168		

Table 21

DIVERSITY OF MACROINVERTEBRATE COMMUNITIES COLLECTED WITH A PONAR DREDGE IN THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - SEPTEMBER 1971

Station	Number of Taxa	Number of Individuals	Diversity ($\bar{d}$)	Equitability (e)
CRM-115	16	74	2.2	0.4
CRM-109	20	217	3.1	0.6
CRM-102.7	15	107	2.9	0.7
CRM-100	17	227	2.4	0.4
CRM-94	24	165	2.9	0.4
CRM-85	22	168	3.5	0.7

Table 22

QUALITATIVE BENTHIC DATA FROM SIX STATIONS ON THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - SEPTEMBER 1971

Taxa	Station Numbers											
	115		109		102.7		100		94		85	
	N	S	N	S	N	S	N	S	N	S	N	S
Spongillidae												
Spongilla sp.				P								
Lophopodidae												
Lophopodella carteri					P							
Pectinatella sp.					P							
Naididae			3		3							
Nais pardalis	1		5									
N. simplex							1					
Pristina sp.							1					
Tubificidae								1		1		13
Branchiura sowerbyi								6				9
Limnodrilus cervix				2				1				1
L. profundicola				1								
Caenidae												
Tricorythodes sp.					1		1					
Heptageniidae												
Stenonema proxium	1											
Saldidae					E							
Saldula sp.	2A											
Corixidae												
Trichocorixa sp.										1		
Sisyridae												
Sisyra sp.				1								
poss. Climacea sp.												1
Hydroptilidae												
Hydroptila sp.	1		1		3C							
Psychomyiidae												
Cyrnellus fraternus	1A		2									
Tipulidae												
Limonia sp.								1				
Ceratopogonidae												
Atrichopogon websteri								1				
Sciaridae	2A											
Chironomidae												
Nanocladius alterantherae		2	1						1			
N. brevinervis					1							
Cricotopus sp. 2 Roback		12	6	1			1	12	1	1		
C. slossonae								1				
C. exilis			2									
C. trifasciatus	1	1	1				4	1	2			
Chironomus attenuatus								1				5

P - Present, E - Eggs, A - Adult, C - Cases

Table 22
(Continued)

Taxa	Station Numbers											
	115		109		102.7		100		94		85	
	N	S	N	S	N	S	N	S	N	S	N	S
Chironomidae												
Xenochironornus xenolabis				1								
Cryptochironomus fulvus					1							
C. ponderosus												1
Tribelos jucundus									2			
Dicrotendipes modestus			1									
D. nervosus		11	16	4			8	5	5	3		
D. nemodestus			2									
Glyptotendipes lobiferus		1			1				1			
Microchironomus sp.												4
Polypedilum illinoense	12	4	8	6			23		5	1		
P. halterale								8				8
Tanytarsus sp. 5 Roback												2
Atanytarsus sp.												1
Total Number of Taxa	8	6	12	8	9	0	7	11	7	5	0	10
Total Number of Individuals	21	31	48	16	7	0	39	38	17	7	0	45

Table 23

TOTAL FISH BIOMASS IN GRAMS COLLECTED FROM THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - SEPTEMBER 1971

	Station							
	Rocky				Clear			
	Day		Night		Day		Night	
	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7
T	8,375	7,524	18,913	35,113	4,272	5,106	8,367	7,964
$\bar{Y}$	2,786	2,508	6,306	11,704	1,424	1,702	2,789	2,656
s	775.4	118.0	1,345.7	4,929.7	901.6	1,525.7	756.5	2,437.0
n	3	3	3	3	3	3	3	3

T - total biomass, $\bar{Y}$ - mean, s - standard deviation, n - number of samples

Table 24

TOTAL NUMBER OF INDIVIDUAL FISH COLLECTED FROM THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - SEPTEMBER 1971

	Station							
	Rocky				Clear			
	Day		Night		Day		Night	
	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7
T	115	184	181	471	53	97	119	232
$\bar{Y}$	38	61	60	157	18	32	40	77
s	8.7	13.1	8.1	74.6	11.7	10.6	2.1	54.3
n	3	3	3	3	3	3	3	3

T - total individuals, $\bar{Y}$ - mean, s - standard deviation, n - number of samples

Table 25

TOTAL NUMBER OF FISH SPECIES COLLECTED FROM THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - SEPTEMBER 1971

	Station							
	Rocky				Clear			
	Day		Night		Day		Night	
	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7
T	8	14	14	13	6	13	15	13
$\bar{Y}$	7	7	11	9	4	5	9	8
s	1.7	2.1	1.7	1.0	2.1	0.6	2.5	3.1
n	3	3	3	3	3	3	3	3

T - total species, $\bar{Y}$ - mean, s - standard deviation, n - number of samples

Table 26

TOTAL FISH BIOMASS COLLECTED IN GRAMS FROM THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - JANUARY 1972

	Station							
	Rocky				Clear			
	Day		Night		Day		Night	
	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7
T	2,553	10,108	398	5,946	1,375	1,530	3,416	3,998
$\bar{Y}$	458	3,369	1,139	1,982	851	510	133	1,333
s	500.0	4,115.9	599.7	2,179.8	196.9	160.1	96.3	946.4
n	3	3	3	3	3	3	3	3

T - total biomass, $\bar{Y}$ - mean, s - standard deviation, n - number of samples

Table 27

TOTAL NUMBER OF INDIVIDUAL FISH COLLECTED FROM THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - JANUARY 1972

	Station							
	Rocky				Clear			
	Day		Night		Day		Night	
	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7
T	47	108	100	102	58	99	43	120
$\bar{Y}$	16	36	33	34	19	33	14	40
s	8.0	42.6	13.3	31.3	14.6	12.5	12.8	3.0
n	3	3	3	3	3	3	3	3

T - total individuals, $\bar{Y}$ - mean, s - standard deviation, n - number of samples

Table 28

TOTAL NUMBER OF FISH SPECIES COLLECTED FROM THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - JANUARY 1972

	Station							
	Rocky				Clear			
	Day		Night		Day		Night	
	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7	CRM-115	CRM-102.7
T	10	12	10	16	12	7	8	13
$\bar{Y}$	7	9	7	9	7	7	6	1
s	2.1	1.0	2.1	1.0	4.0	1.2	2.1	2.1
n	3	3	3	3	3	3	3	3

T - total species, $\bar{Y}$ - mean, s - standard deviation, n - number of samples

Table 29

SCIENTIFIC AND COMMON NAMES OF FISHES COLLECTED ELECTROFISHING IN CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE

Lepisosteus platostomus Rafinesque - Shortnose gar

Alosa chrysochloris (Rafinesque) - Skipjack herring

Dorosoma cepedianum (LeSueur) - Gizzard Shad

Cyprinus carpio Linneaus - Carp

Hybopsis amblops (Rafinesque) - Bigeye chub

Notropis atherinoides Rafinesque - Emerald shiner

Notropis blennius (Girard) - River shiner

Notropis galacturus (Cope) - Whitetail shiner

Notropis hudsonius (Clinton) - Spottail shiner

Notropis spilopterus (Cope) - Spotfin shiner

Pimephales vigilax (Baird & Girard) - Bullhead minnow

Notropis volucellus (Cope) - Mimic shiner

Hypentelium nigricans (LeSueur) - Northern hogsucker

Ictiobus bubalus (Rafinesque) - Smallmouth buffalo

Minytrema melanops (Rafinesque) - Spotted sucker

Moxostoma carinatum (Cope) - River redhorse

Moxostoma duquesnei (LeSueur) - Black redhorse

Ictalurus melas (Rafinesque) - Black bullhead

Ictalurus punctatus (Rafinesque) - Channel catfish

Anguila rostrata (LeSueur) - American eel

Roccus chrysops (Rafinesque) - White bass

Roccus mississippiensis (Jordan & Eigenmann) - Yellow bass

Ambloplites rupestris (Rafinesque) - Rock bass

Table 29
(Continued)

Micropterus punctulatus (Rafinesque) - Spotted bass

Micropterus salmoides (Lacepede) - Largemouth bass

Pomoxis annularis Rafinesque - White crappie

Pomoxis nigromaculatus (LeSueur) - Black crappie

Etheostoma rufilineatum (Cope) - Redline darter

Percina caprodes (Rafinesque) - Logperch

Stizostedion canadense (Smith) - Sauger

Aplodinotus grunniens Rafinesque - Freshwater drum

Labidesthes sicculus (Cope) - Brook silversides

Table 30

SPECIES COMPOSITION OF FISH COLLECTED WITH AN ELECTRIC SHOCKER FROM THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE
SEPTEMBER 1971

Species Collected	Station CRM-115				Station CRM-102.7			
	% of Total		Size Range	Avg. Size	% of Total		Size Range	Avg. Size
	No.	Wt.	(cm)	(cm)	No.	Wt.	(cm)	(cm)
GROUP I								
Shortnose Gar					<1	2	73	73
White Bass					<1	<1	6-16	11
Yellow Bass								
Spotted Bass	4	5	7-28	20.7	1	5	15-40	25
Largemouth Bass	1	10	18-42	34	1	4	6-45	21
White Crappie	<1	<1	14-18	15.7	<1	<1	26	26
Black Crappie	<1	<1	16	16	<1	<1	9-19	13
Sauger					<1	<1	35	35
GROUP II								
Bigeye Chub	<1	<1	--	--				
Emerald Shiner	2	<1	--	--	7	<1	--	--
River Shiner	<1	<1	--	--	<1	<1	--	--
Whitetail Shiner	<1	<1	--	--	<1	<1	--	--
Spottail Shiner	<1	<1	--	--				
Spotfin Shiner					<1	<1	--	--
Bullhead Minnow	1	<1	--	--	<1	<1	--	--
Mimic Shiner	<1	<1	--	--				
Rock Bass	<1	<1	14	14				
Green Sunfish					<1	<1	11-13	12
Bluegill	37	27	4-19	13.6	43	30	4-18	12
Longear Sunfish	20	10	8-17	12.5	12	7	4-16	11
Log Perch	1		8	8	<1	<1	7-10	8
Silversides	<1		--	--	<1	<1	--	--
GROUP III								
Skipjack					3	<1	--	--
Gizzard Shad	23	21	6-30	23	24	12	8-28	23
Threadfin Shad	<1	<1	--	--	<1	<1	--	--
GROUP IV								
River Redhorse	<1	<1	36	36				
Drum					<1	<1	8-20	16
GROUP V								
Spotted Sucker	<1	<1	27	27				
Hog Sucker	<1	<1	20	20				
GROUP VI								
Carp	5	25	27-42	31.9	3	25	27-47	32
Smallmouth Buffalo					<1	1	36	36
Channel Catfish	2	<1	14-23	19.2	<1	4	12-52	32
Total Number of Fish	468				962			
Total Weight of Fish	39.92 kg. (88.01 lb.)				55.71 kg. (122.83 lb.)			

Table 31

SPECIES COMPOSITION OF FISH COLLECTED WITH AN ELECTRIC SHOCKER FROM THE CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE - JANUARY 1972

Species Collected	Station CRM-115				Station CRM-102.7			
	% of Total		Size Range (cm)	Avg. Size (cm)	% of Total		Size Range (cm)	Avg. Size (cm)
	No.	Wt.			No.	Wt.		
GROUP I								
White Bass	<1	<1	16	16	<1	1	14-25	19
Largemouth Bass	--	--			<1	23	45-47	46
Spotted Bass	4	15	7-35	15	--	--		
Black Crappie	2	2	11-20	15	4	12	14-27	22
Sauger	<1	2	29	29	<1	2	16-26	23
GROUP II								
Emerald Shiner	13				28			
River Shiner	4				11			
Striped Shiner	8				5			
Spotfin Shiner	<1				2			
Whitetail Shiner	2	5			1	2		
Steelcolor Shiner	3				<1			
Mimic Shiner	--				<1			
Darter	--				<1			
Bullhead Minnow	22				15			
Green Sunfish	<1	<1	5	5	<1	<1	6-7	6
Bluegill	4	8	5-19	14	4	2	5-17	11
Longear Sunfish	8	9	8-15	12	3	2	9-14	13
GROUP III								
Gizzard Shad	10	16			6	7		
GROUP IV								
Black Redhorse	1	9	23-38	30	--	--		
Drum	15	23			10	12		
GROUP V								
None								
GROUP VI								
Carp	<1	7	34	34	2	31	29-46	37
Channel Catfish	--	--			<1	3	27-36	30
Black Bullhead	<1	3	25	25	--	--		
Total Number of Fish	248				429			
Total Weight of Fish	7.74 kg (17.07 lb.)				21.58 kg. (47.58 lb.)			

Table 32

HABITAT PREFERENCE OF FISH FROM TWO STATIONS ON THE CUMBERLAND RIVER
SEPTEMBER 1971 AND JANUARY 1972

Station	September 1971						January 1972					
	Day			Night			Day			Night		
	# of Ind.	# of Sp.	Biomass	# of Ind.	# of Sp.	Biomass	# of Ind.	# of Sp.	Biomass	# of Ind.	# of Sp.	Biomass
CRM-115												
Rocky	115	8	8,375	181	14	18,913	47	10	2,553	100	16	398
Clear	53	6	4,272	119	15	8,367	53	12	1,375	45	13	3,416
CRM-102.7												
Rocky	184	14	7,524	471	13	35,113	108	12	10,108	102	16	5.946
Clear	97	13	5,106	232	13	7,964	99	7	1,530	120	13	3,998

Table 33

SPECIES COMPOSITION OF FISH COLLECTED BOTH DAY AND NIGHT FROM TWO STATIONS ON THE CUMBERLAND RIVER - SEPTEMBER 1971 AND JANUARY 1972

Species	September 1971				January 1972			
	CRM-115		CRM-102.7		CRM-115		CRM-102.7	
	Day	Night	Day	Night	Day	Night	Day	Night
GROUP I								
Largemouth Bass		X	X	X			X	X
Spotted Bass	X	X	X	X	X	X		
White Bass				X	X		X	X
Yellow Bass				X				
White Crappie		X		X	X			X
Black Crappie		X		X	X	X	X	X
Sauger		X		X	X			X
Shortnose Gar			X					
GROUP II								
Green Sunfish			X			X	X	X
Longear Sunfish	X	X	X	X	X	X	X	X
Bluegill	X	X	X	X	X	X	X	X
Rock Bass	X							
Log Perch	X	X	X	X				
Silversides		X	X	X				
Darter								X
Bullhead Minnow	X		X	X	X	X	X	X
Bigeye Chub		X						
Emerald Shiner	X	X	X	X	X	X	X	X
River Shiner	X		X		X		X	X
Whitetail Shiner		X	X		X			X
Spottail Shiner		X						
Spotfin Shiner			X		X		X	X
Mimic Shiner		X					X	
Steelcolor Shiner						X		X
Striped Shiner					X	X		X
GROUP III								
Gizzard Shad	X	X	X	X	X	X	X	X
Threadfin Shad	X		X					
Skipjack	X		X					
GROUP IV								
Black Redhorse					X	X		
River Redhorse		X						
Drum		X	X	X		X		X
GROUP V								
Spotted Sucker		X						
Hog Sucker	X							
GROUP VI								
Carp	X	X	X	X	X		X	X
Smallmouth Buffalo				X				
Channel Catfish		X	X	X			X	X
Black Bullhead					X			

Table 34

TOTAL NUMBER, WEIGHT, AND SPECIES OF FISH COLLECTED FROM TWO STATIONS ON THE CUMBERLAND RIVER - SEPTEMBER 1971 AND JANURAY 1972

Station	Number of Individuals		Number of Species		Weight	
	September	January	September	January	September	January
CRM-115	468	248	23	19	39.92	7.74
CRM-102.7	962	429	24	20	55.71	21.58

FIGURE 2

BOTTOM PROFILE OF THE CUMBERLAND RIVER AT MM 85

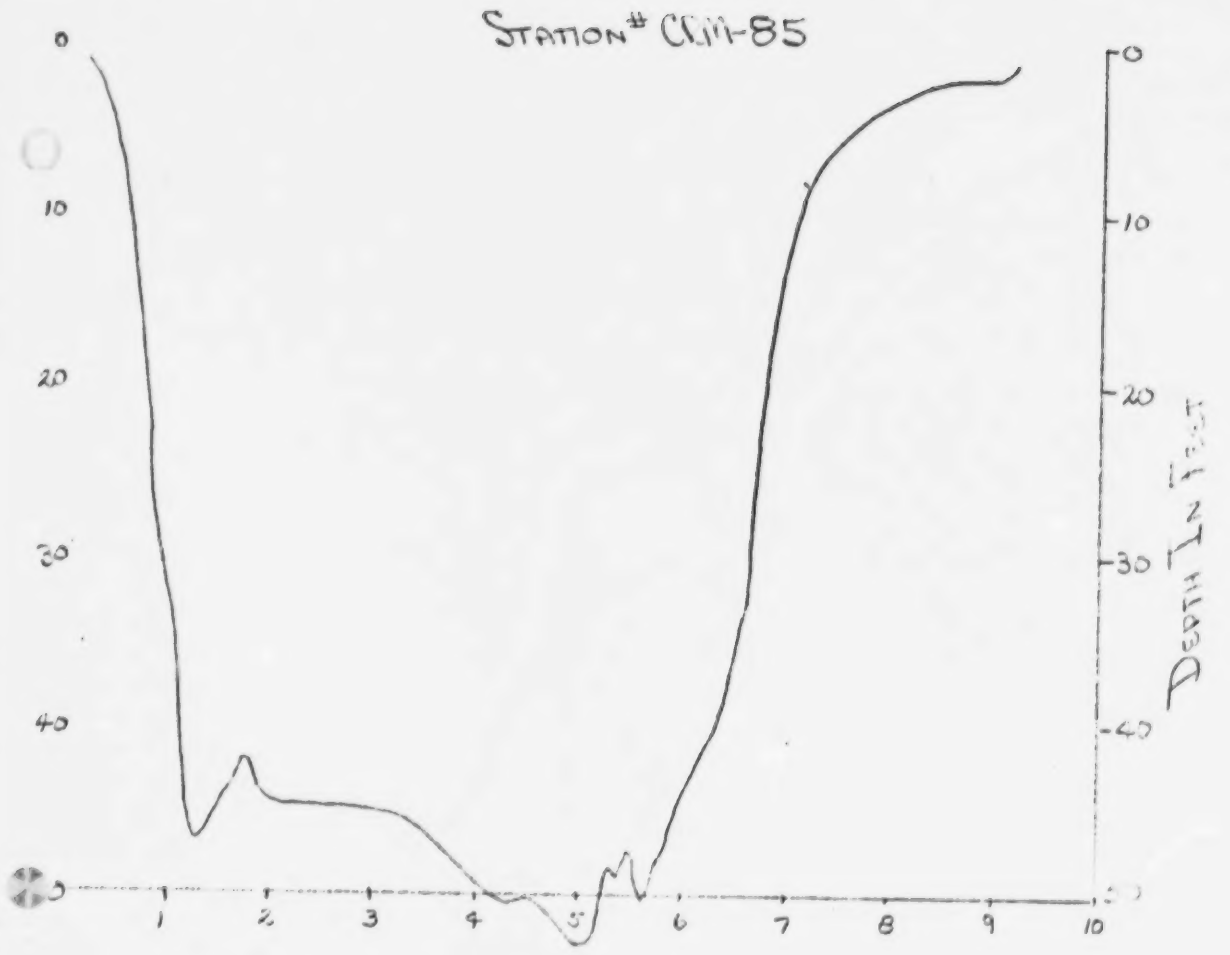


FIGURE 4
BOTTOM PROFILE OF THE CUMBERLAND RIVER AT R.M. 97

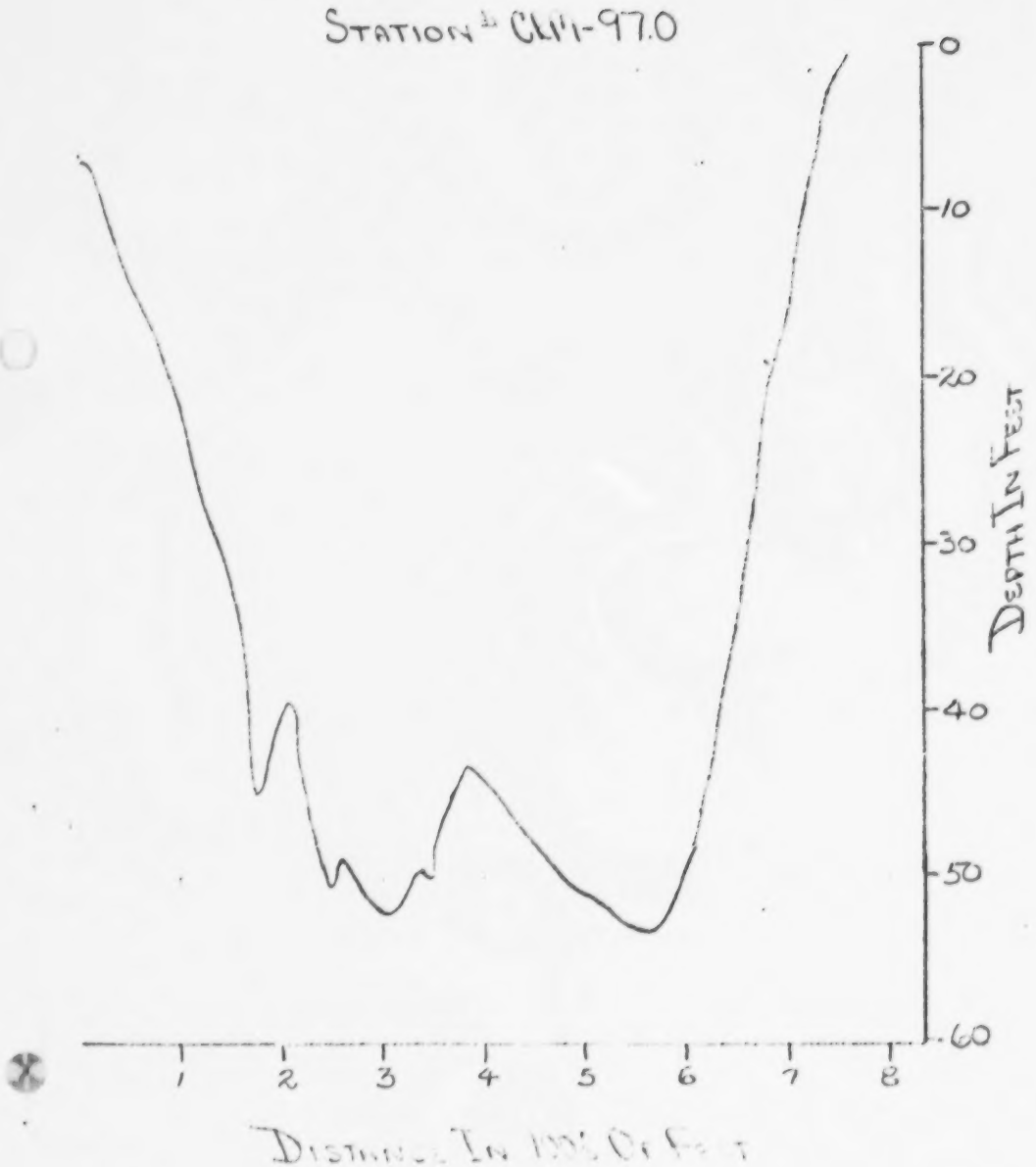


FIGURE 3

BOTTOM PROFILE OF THE CUMBERLAND RIVER AT R. M. 94.1

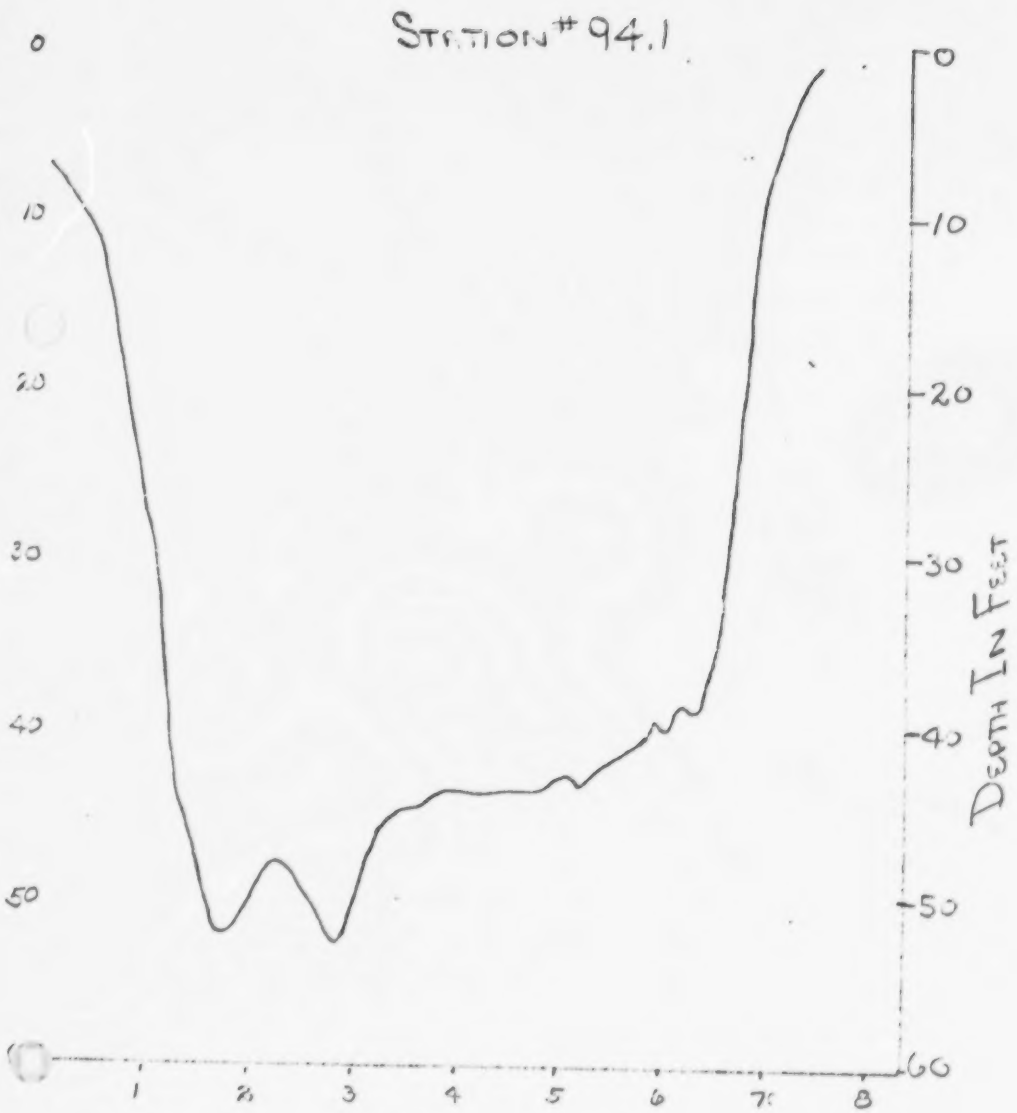


FIGURE 5

BOTTOM PROFILE OF THE CURRITUCK SOUND RIVER AT [illegible] 100

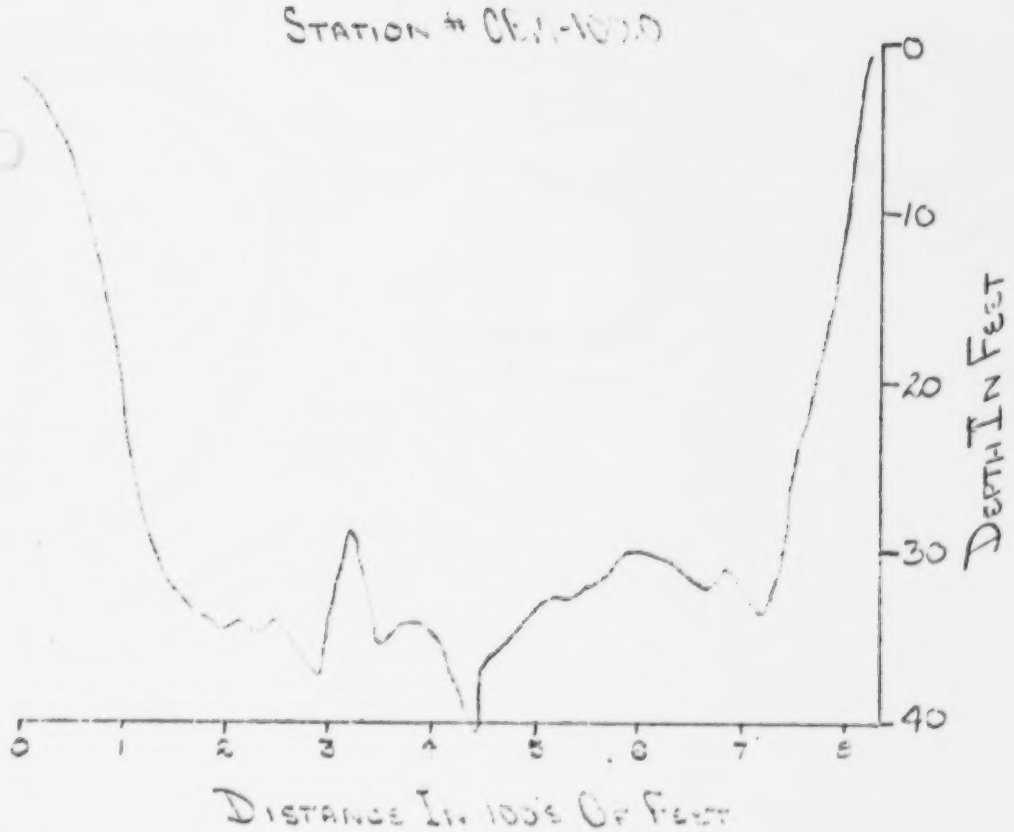
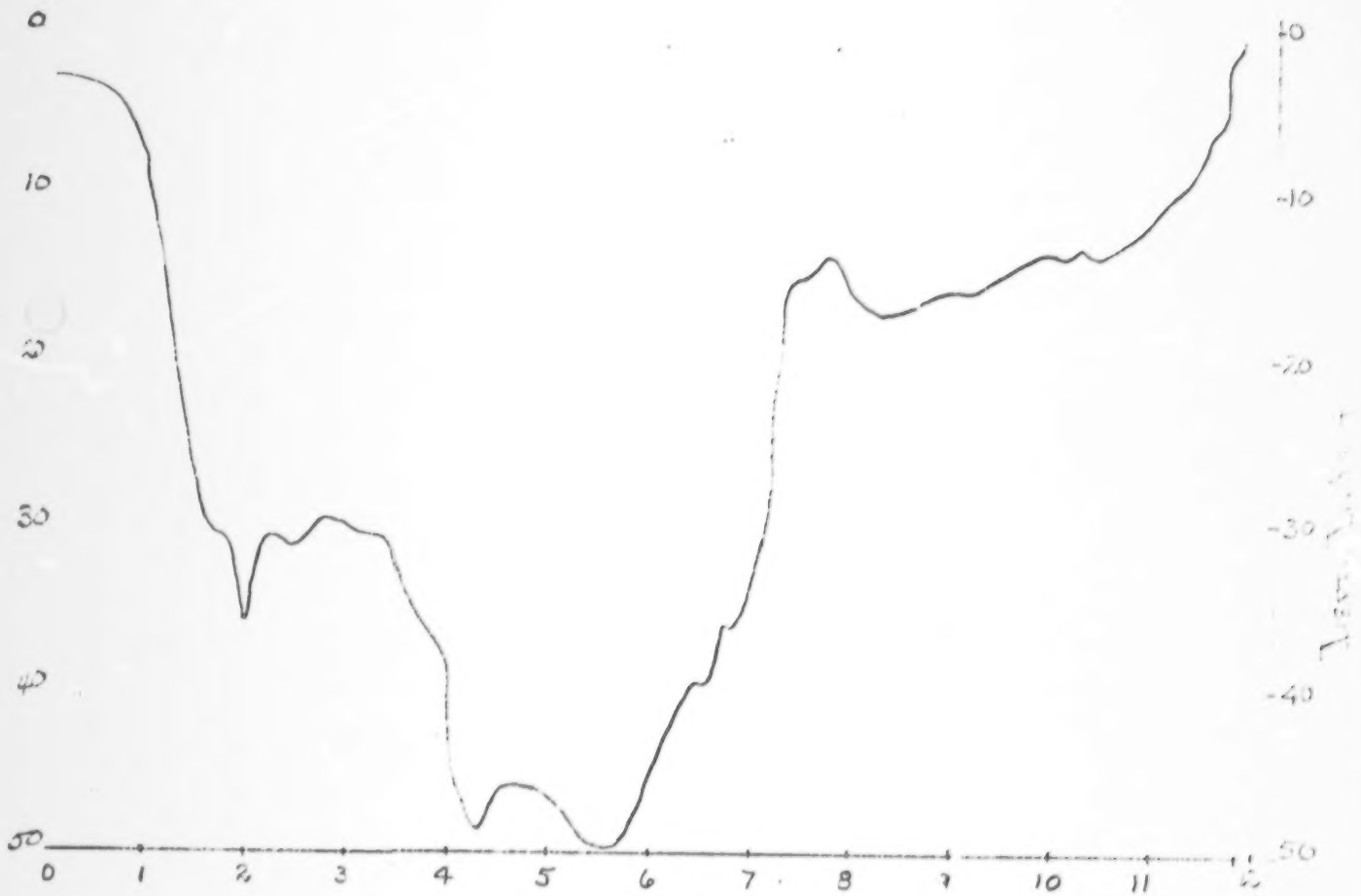


FIGURE 6
BOTTOM PROFILE OF THE CUMBERLAND
PANEL AT STA. 102.7

STATION # CUM-102.7



DISTANCE IN 100's OF FEET

FIGURE 7

BOTTOM PROFILE OF THE CUMBERLAND RIVER AT T.V.A. 103R

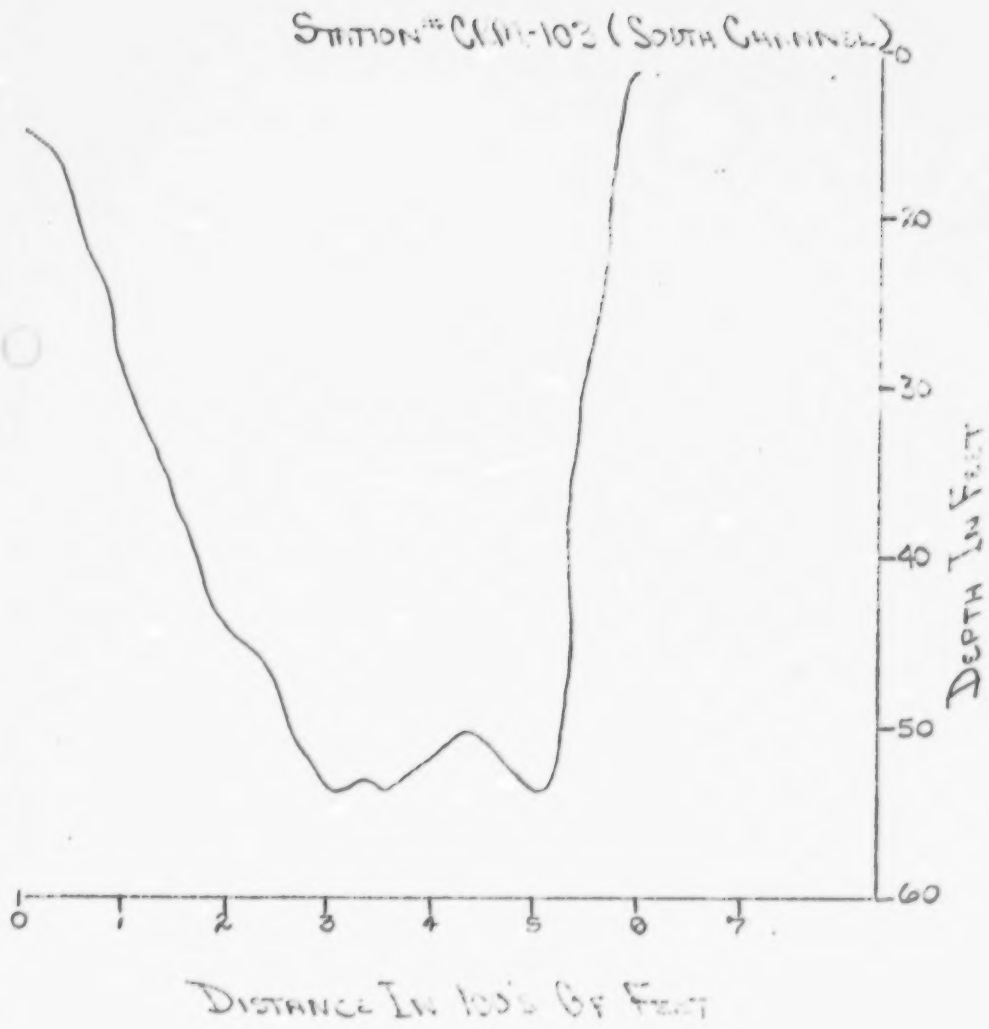


FIGURE 8

BOTTOM PROFILE OF THE CUMBERLAND RIVER AT MILE 1036

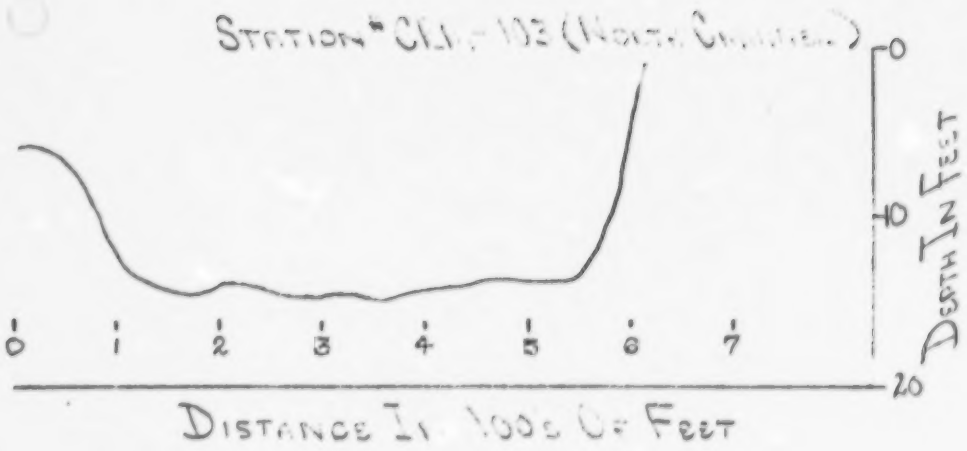


FIGURE 9
BOTTOM PROFILE OF THE COLUMBIA
RIVER AT RM 106

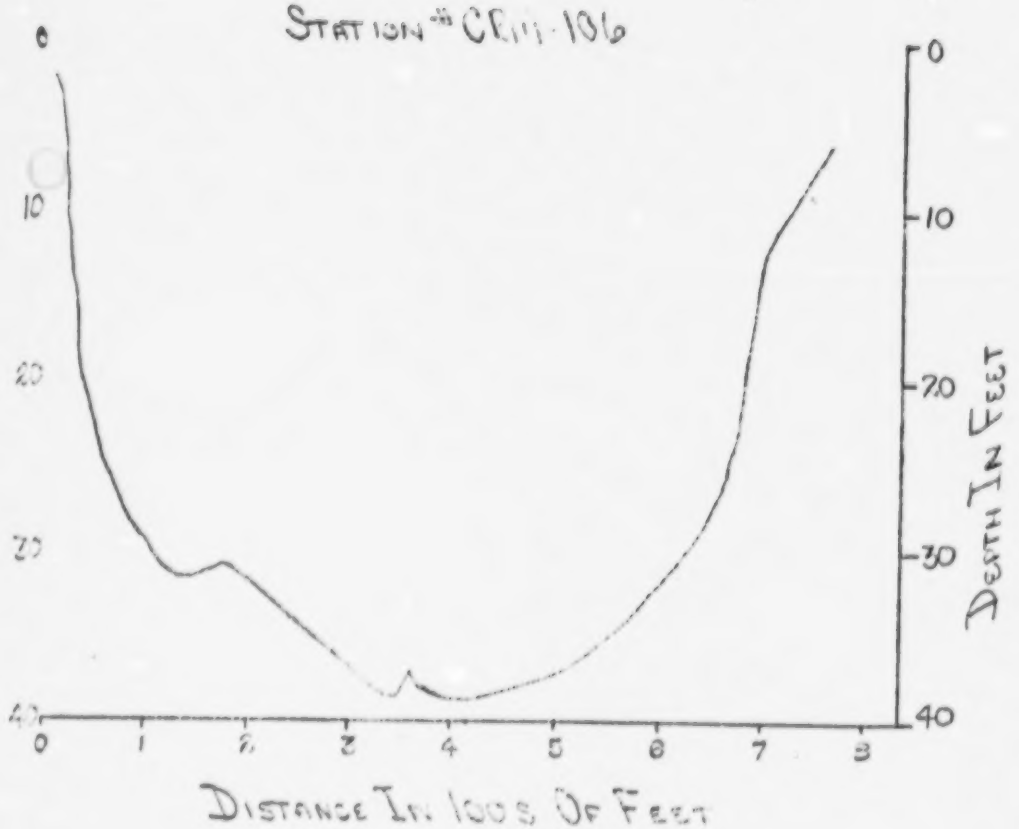


FIGURE 10

BOTTOM PROFILE OF THE [illegible]
[illegible] FOR RUN 109

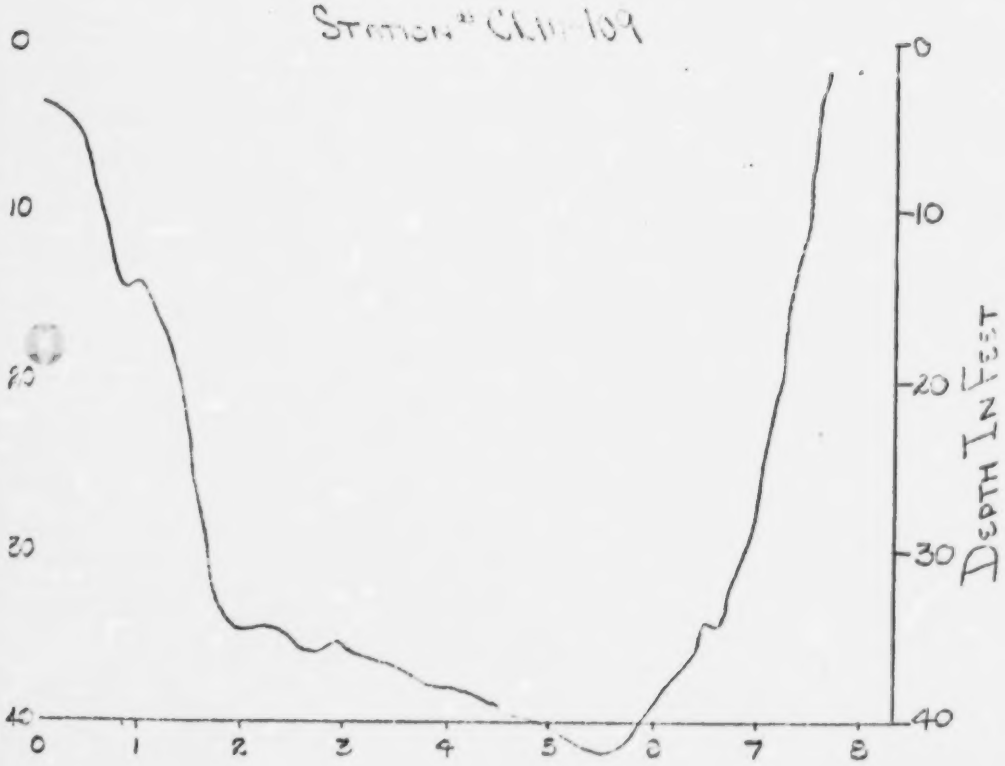


FIGURE 11
BOTTOM PROFILE OF THE CUMBERLAND
RIVER AT CRM-115

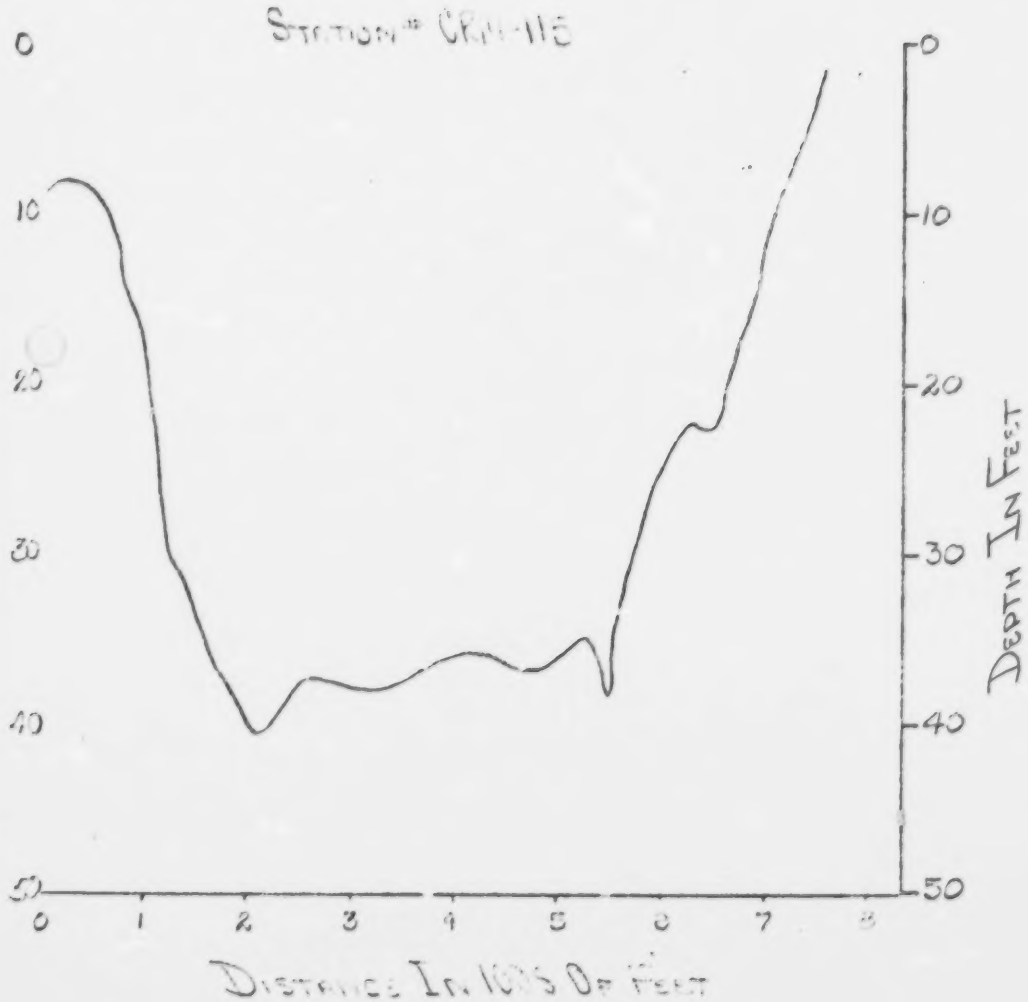


FIGURE 12

TEMPERATURE PROFILE AT STATION CL-1115, CUMBERLAND
NEAR CUMBERLAND CITY TERMINAL
SEPTEMBER, 1971

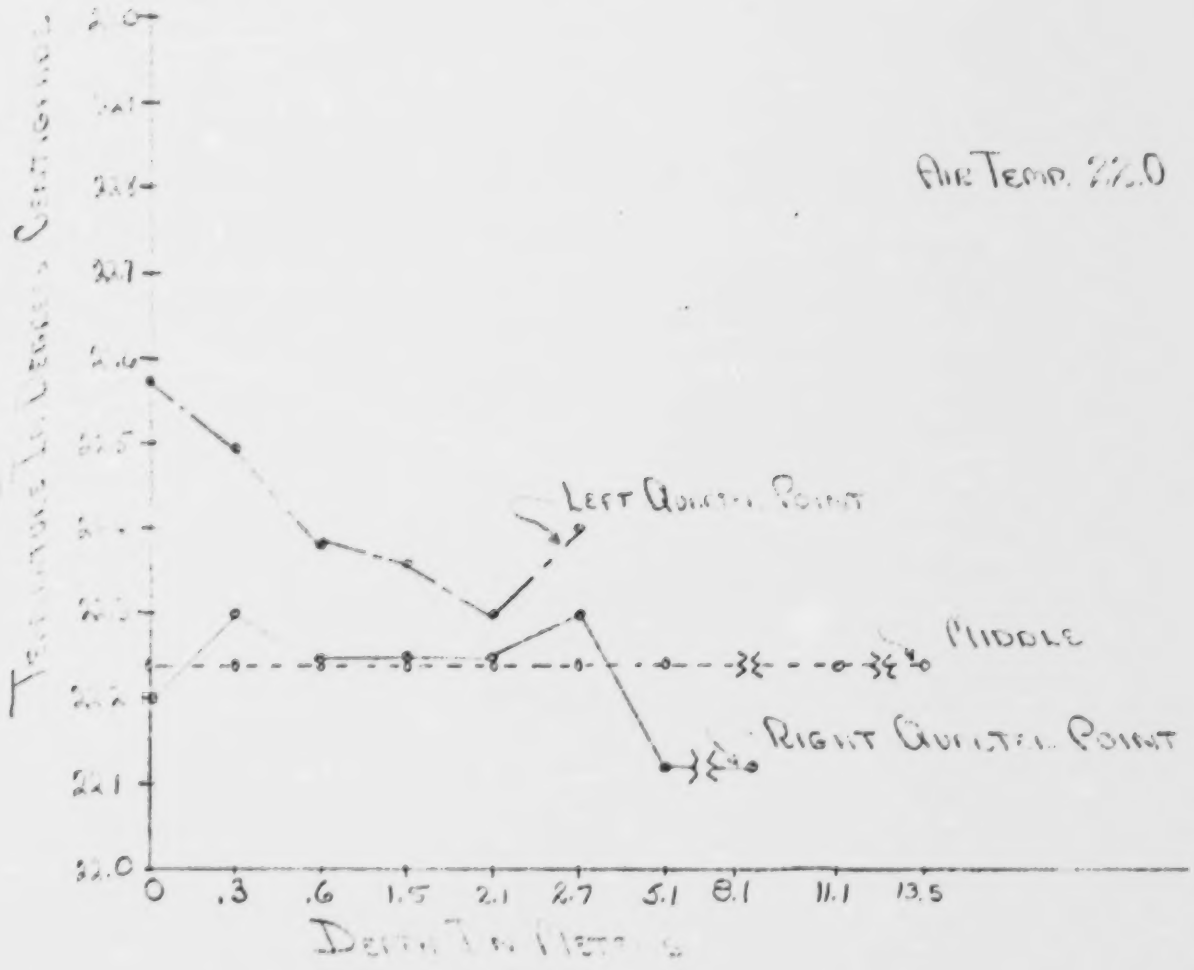


FIGURE 13

TEMPERATURE PROFILE AT STATION CUMB3 CUMBERLAND RIVER
NEAR CUMBERLAND CITY, TENNESSEE
SEPTEMBER, 1971

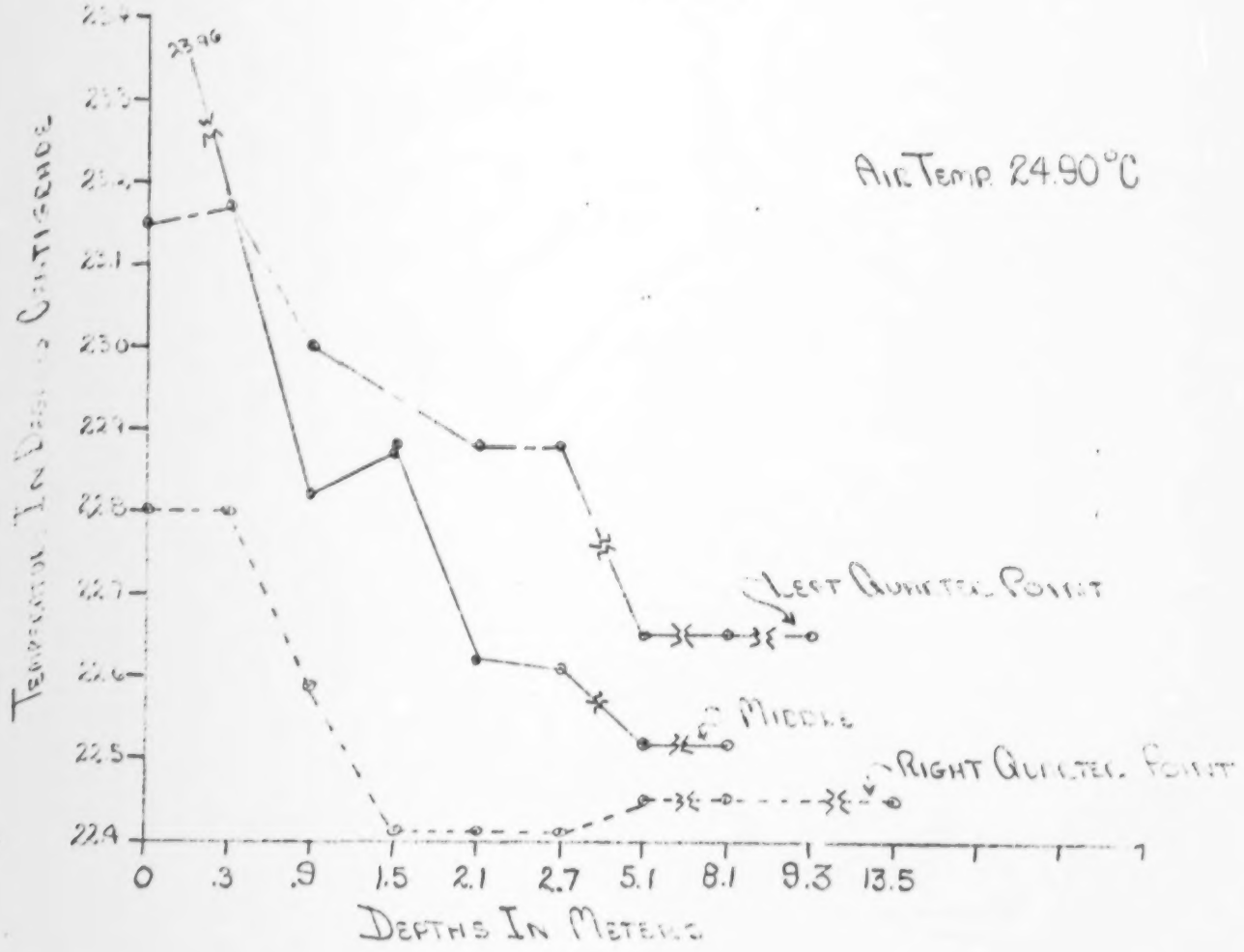


FIGURE 14

TEMPERATURE PROFILE AT STATION C1 1106 CORPUS CHRISTI BAY NEAR CORPUS CHRISTI CITY, TEXAS

SEPTEMBER, 1971

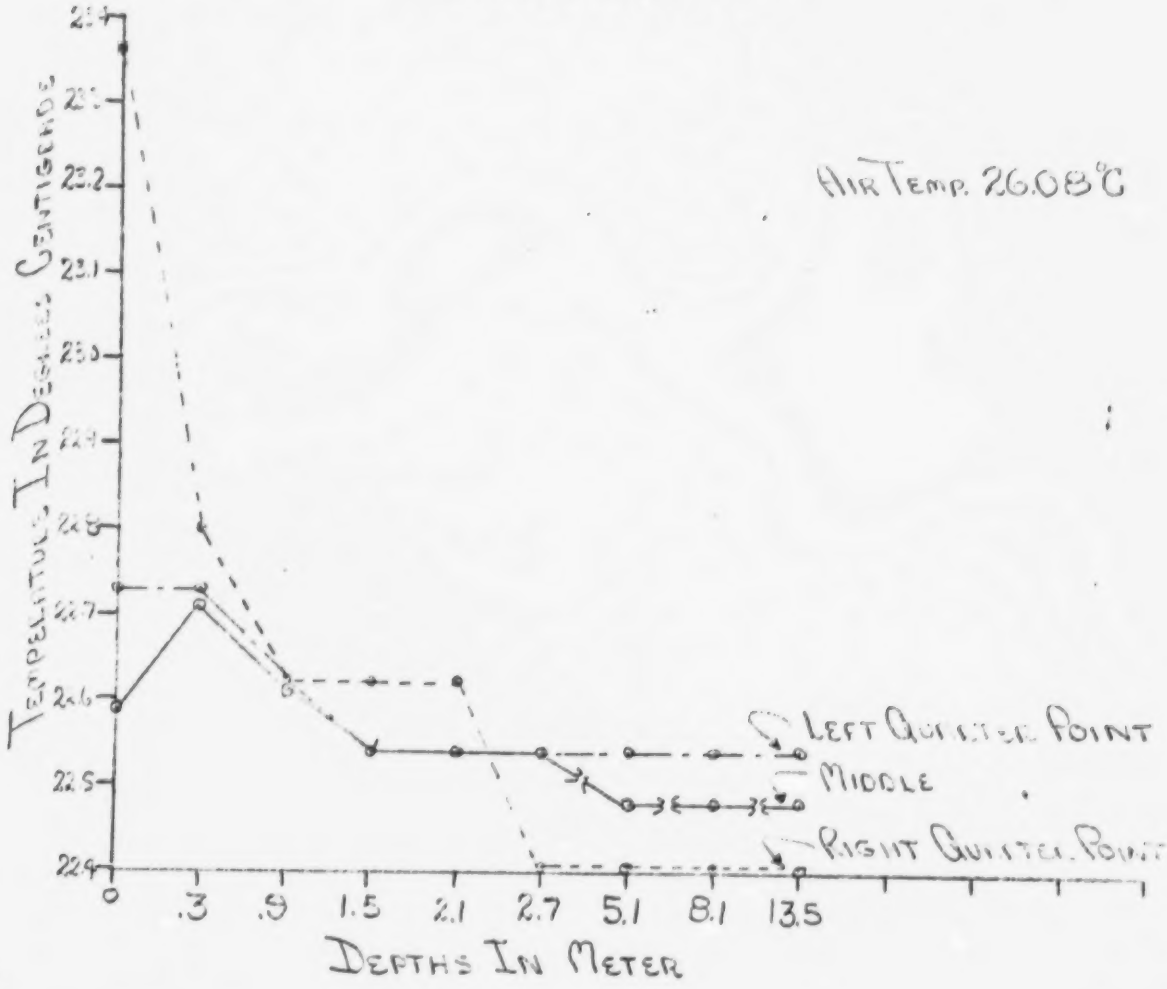


FIGURE 15

TEMPERATURE PROFILE AT STATION CRM 103 (NEW CHANNEL)
CUMBERLAND RIVER, CUMBERLAND CITY, TENNESSEE
SEPTEMBER, 1971

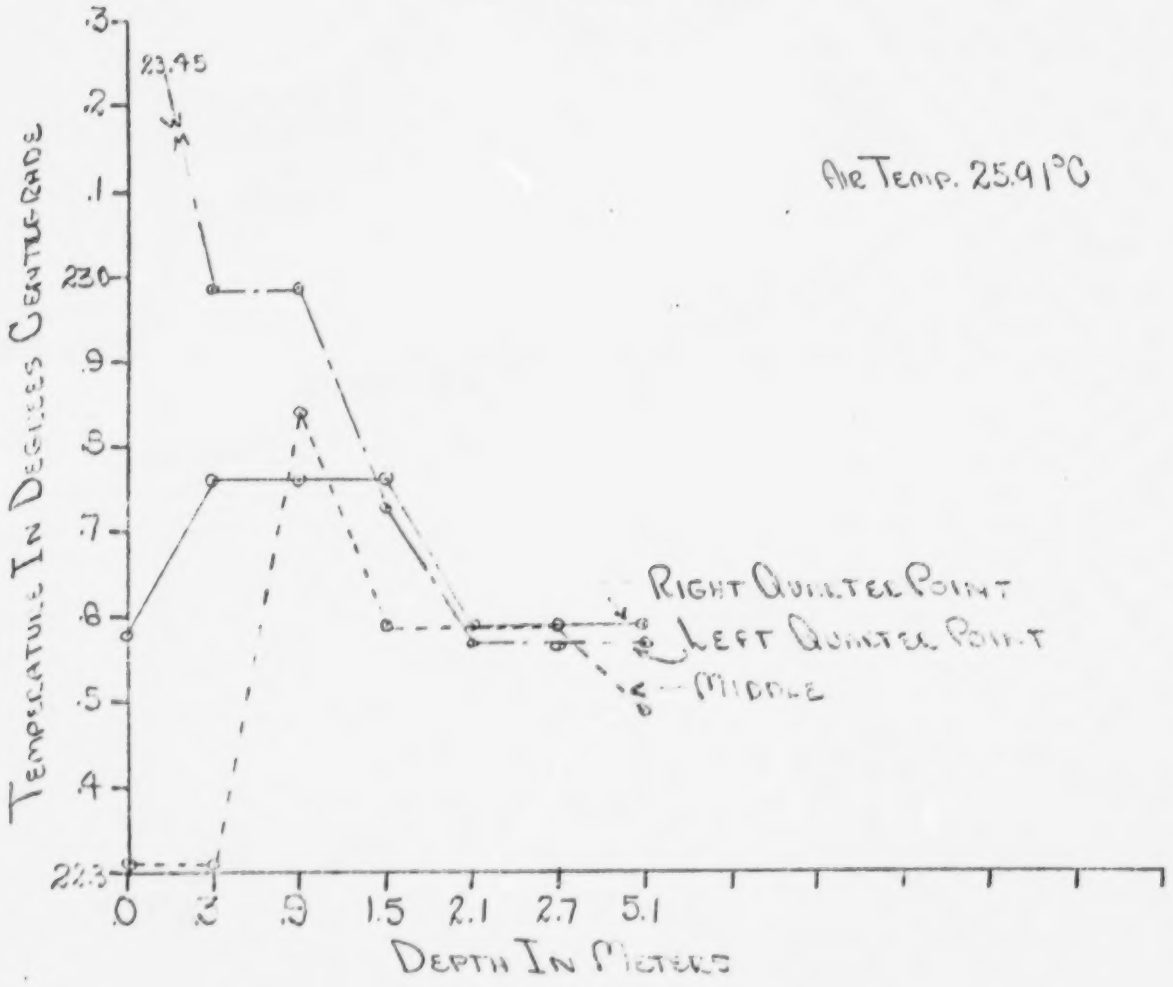


FIGURE 16

TEMPERATURE PROFILE AT STATION CR-110% (OLD CHANNEL)
CUMBERLAND RIVER, CUMBERLAND CITY, TENNESSEE
SEPTEMBER, 1971

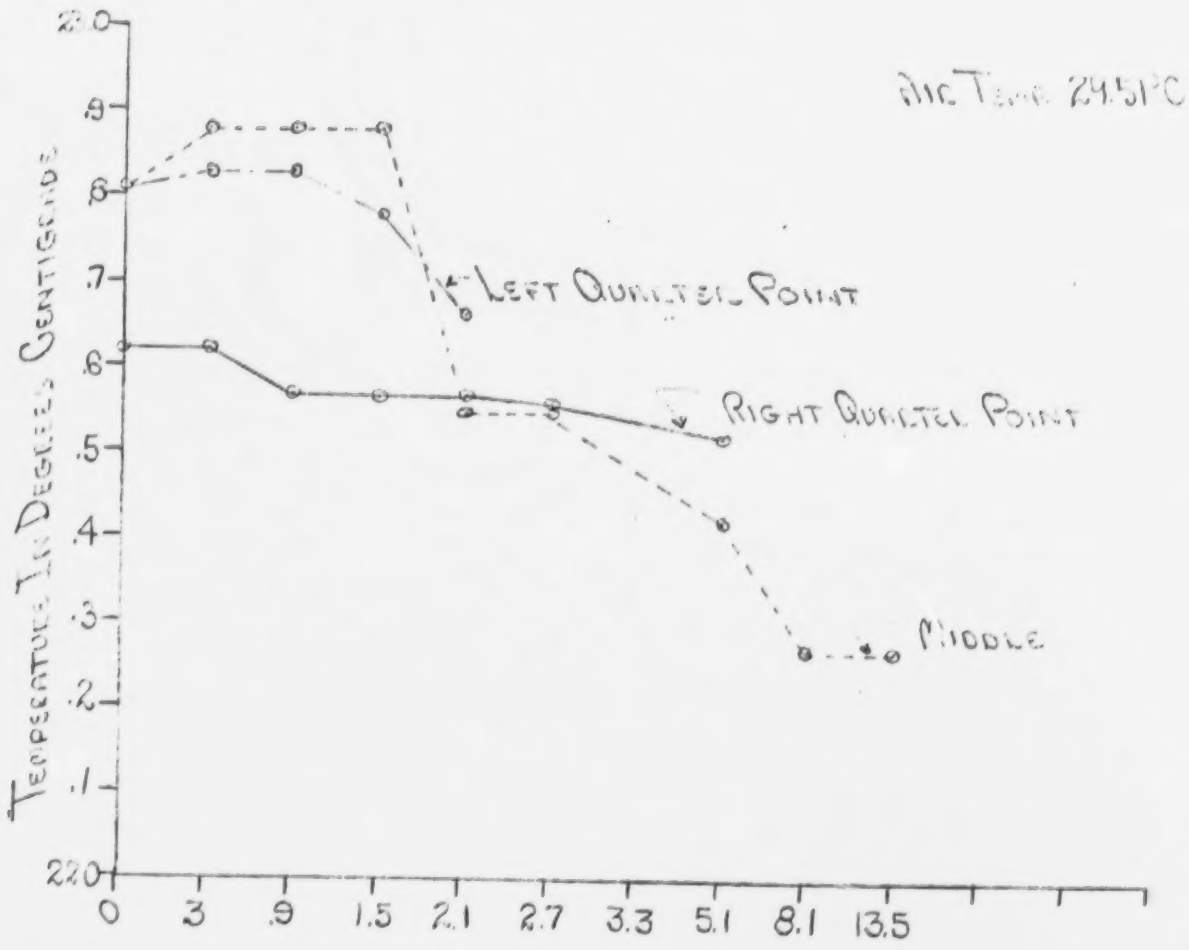


FIGURE 17

TEMPERATURE PROFILE AT STATION CL-102.7 CUMBERLAND RIVER NEAR CUMBERLAND CITY, TENNESSEE SEPTEMBER, 1971

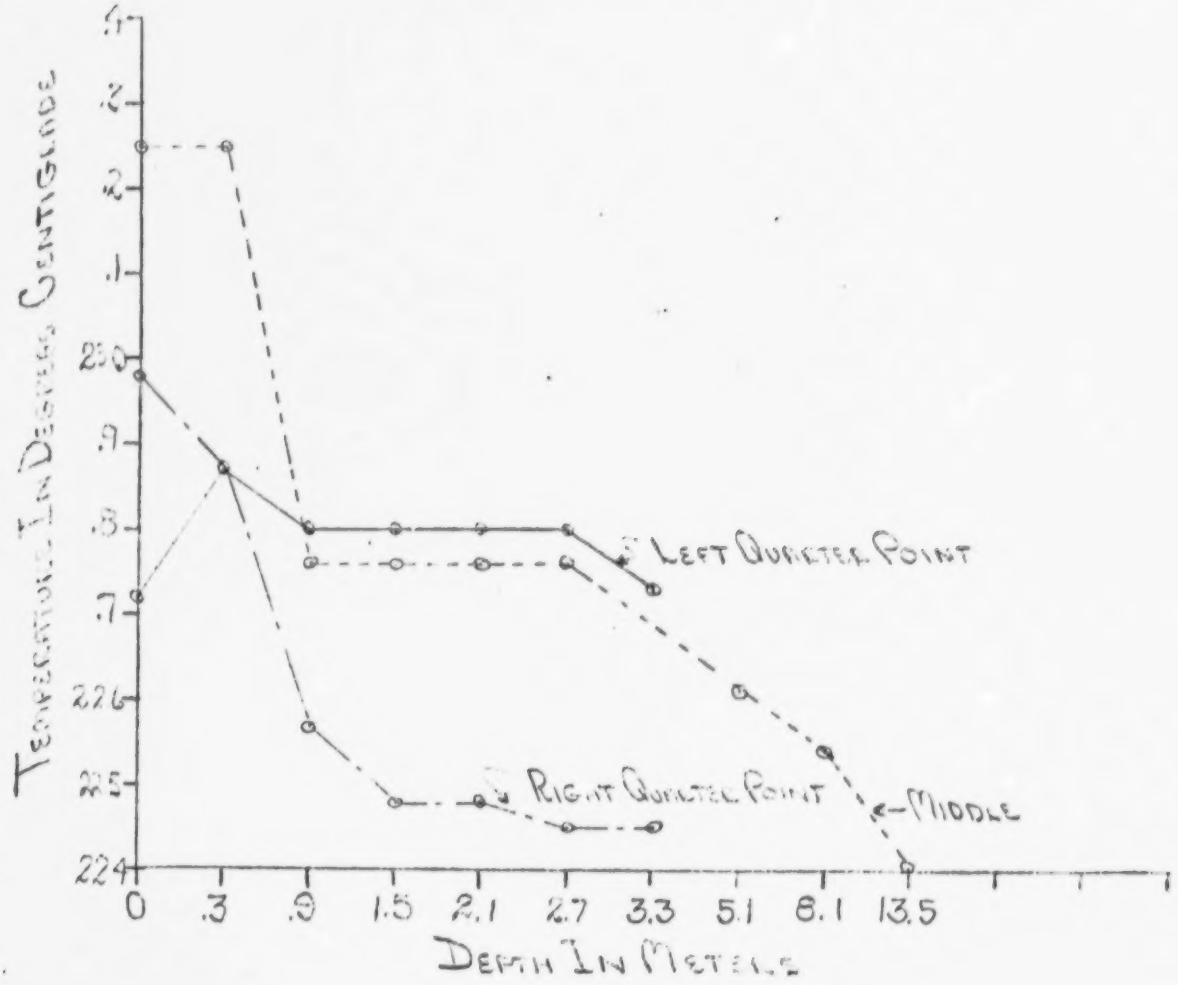


FIGURE 18

TEMPERATURE PROFILE AT STATION CRM 100 CUMBERLAND RIVER
NEAR CUMBERLAND CITY, TENNESSEE
SEPTEMBER, 1971

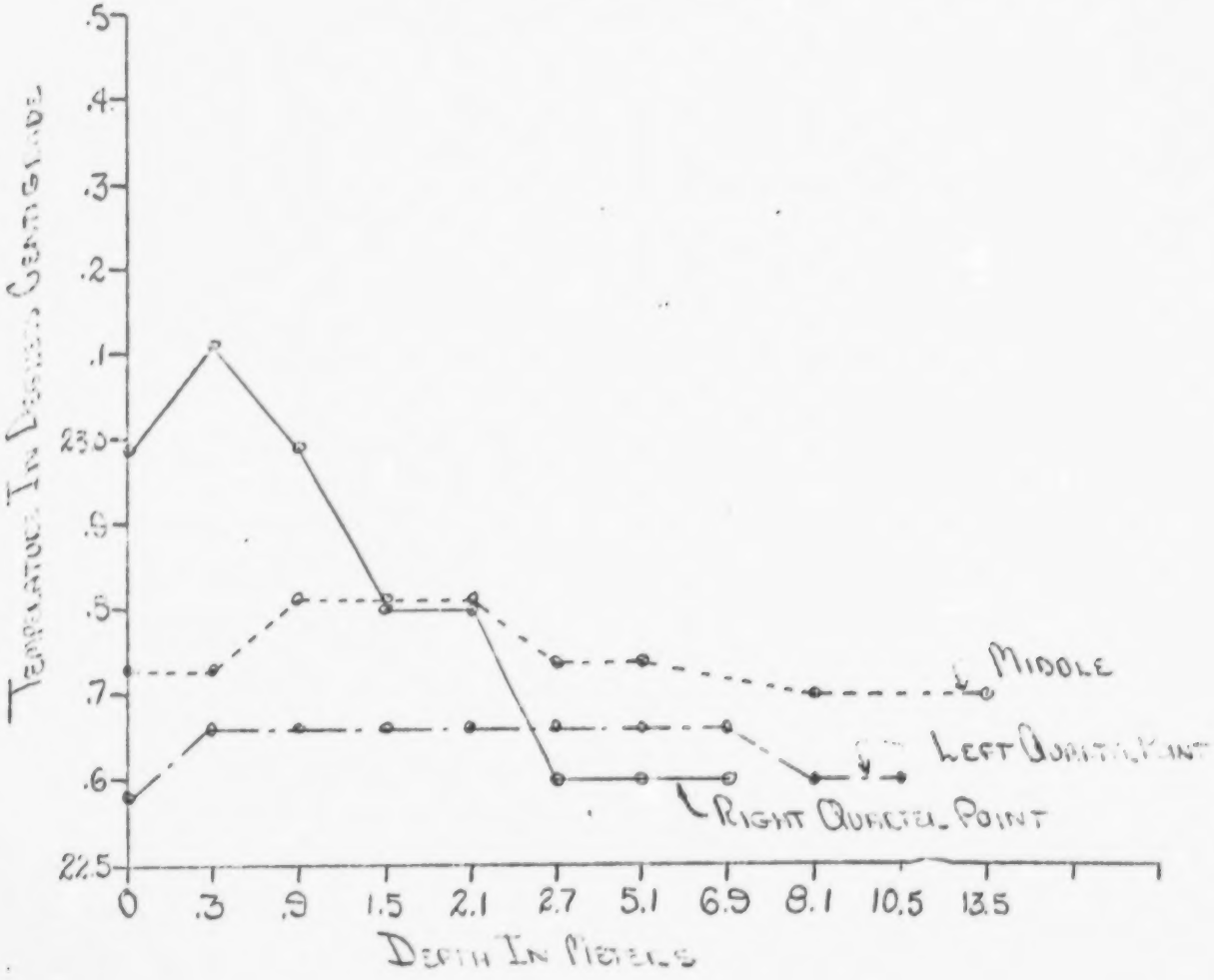


FIGURE 19

TEMPERATURE PROFILE AT STATION CRM 87 CUMBERLAND RIVER
NEAR CUMBERLAND CITY, TENNESSEE
SEPTEMBER, 1971

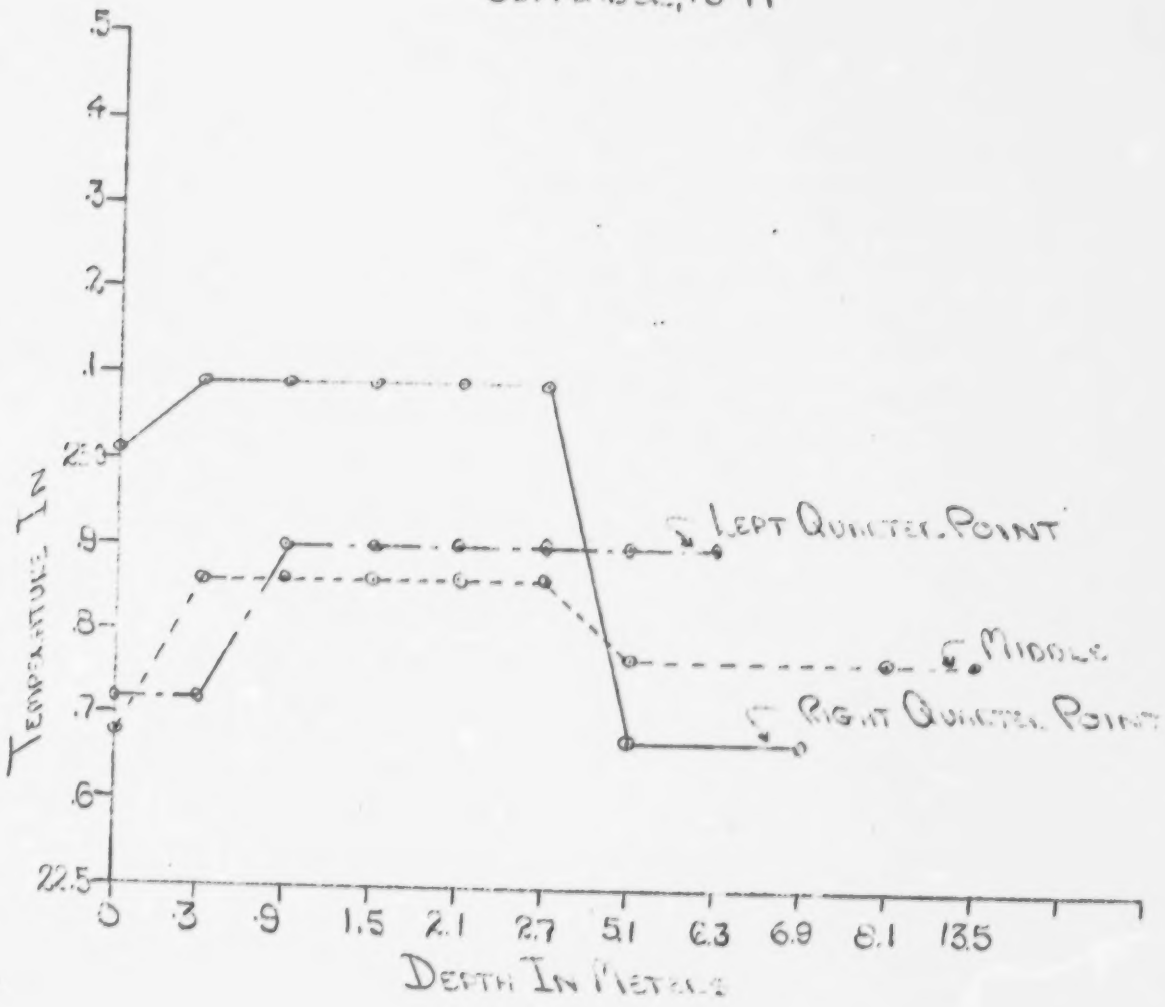


FIGURE 20

TEMPERATURE PROFILE AT STATION CR-194 CUMBERLAND RIVER
NEAR CUMBERLAND CITY, TENNESSEE
SEPTEMBER, 1971

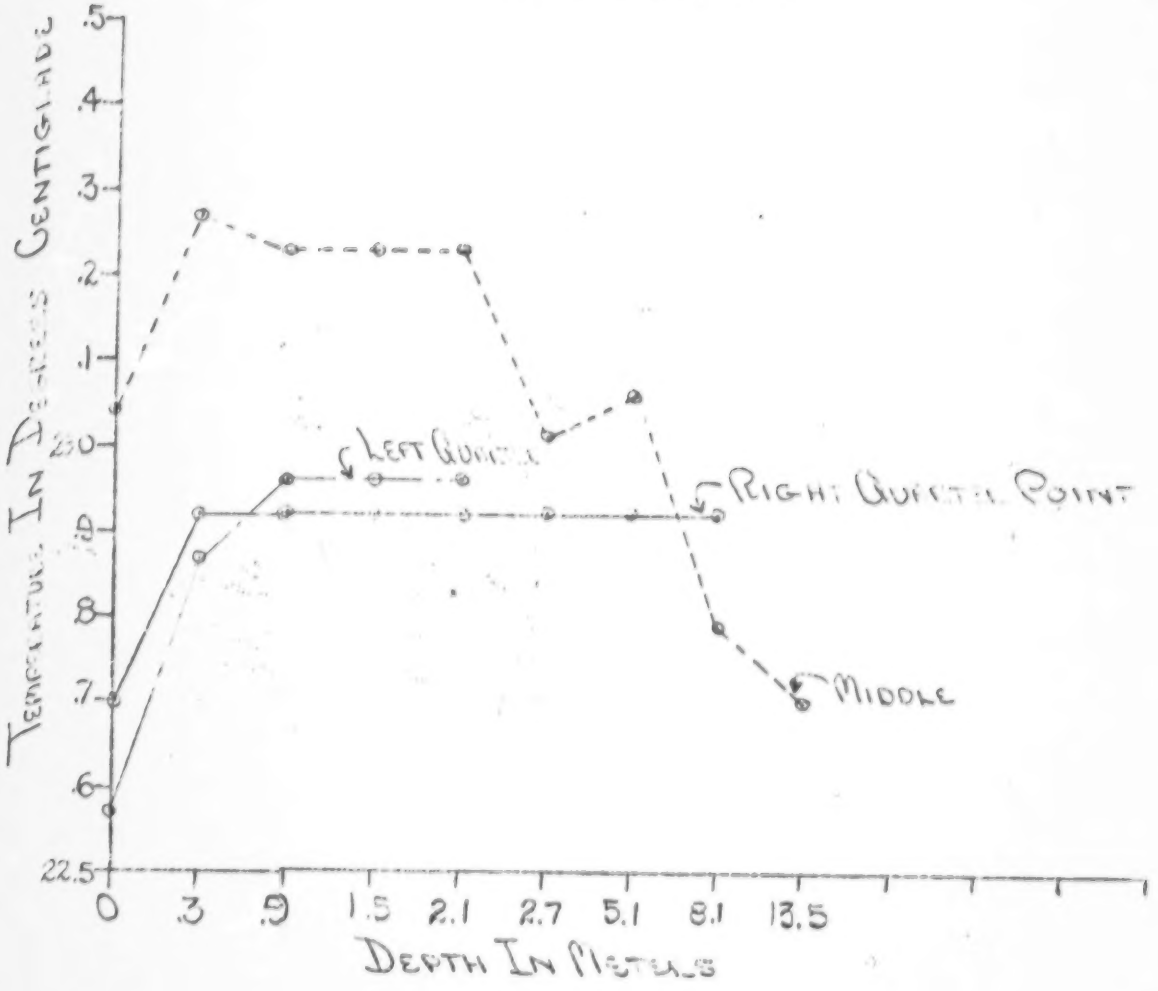


FIGURE 21

TWENTY-FOUR HOUR DISSOLVED OXYGEN PROFILE AT THE RIGHT QUARTER POINT OF STATION [illegible]109
SEPTEMBER, 1971

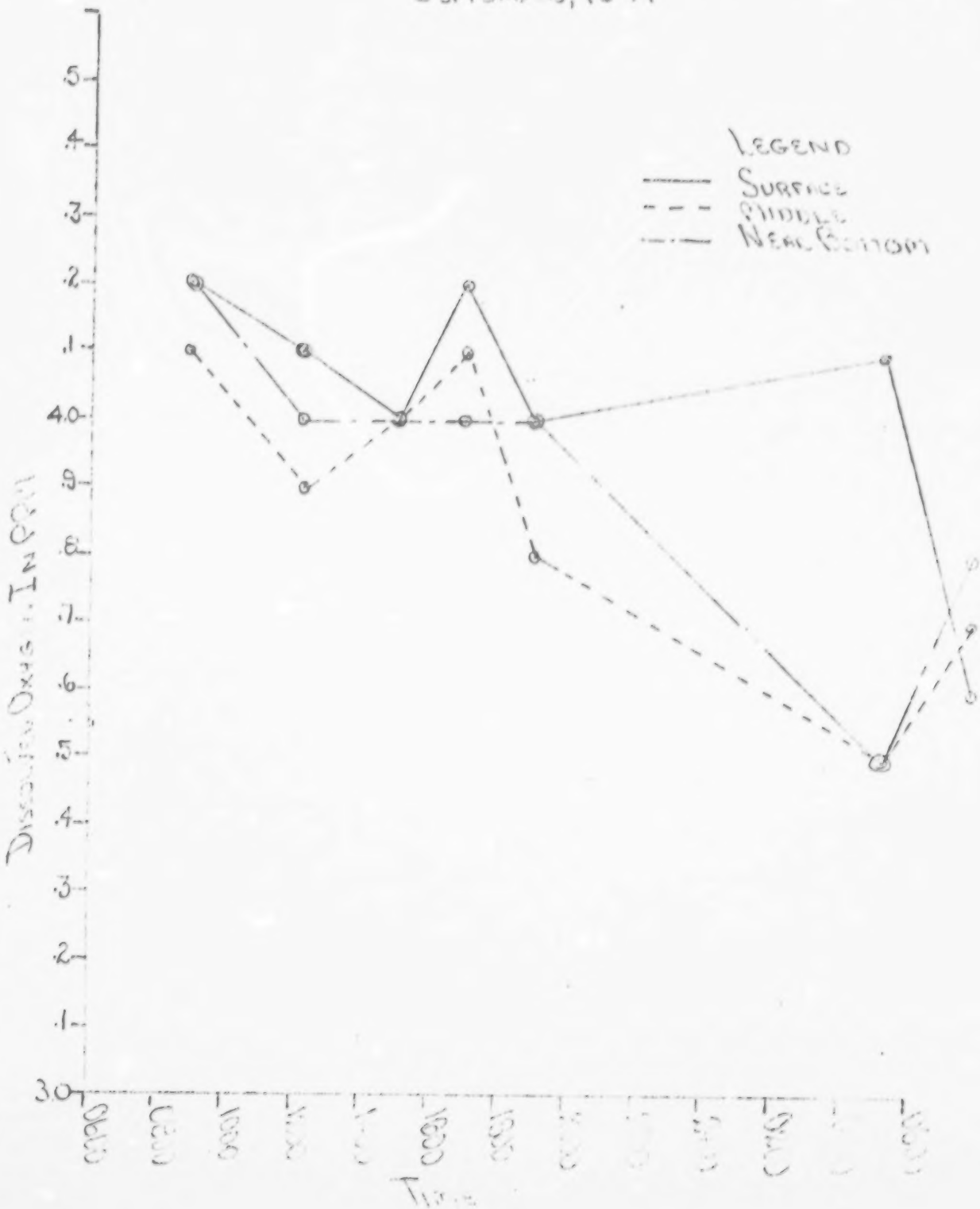


FIGURE 22

TWELFTH-FOUR HOUR, DISSOLVED OXYGEN PROFILE AT
THE CHANNEL OF STRAWBERRY CANYON
SEPTEMBER, 1971

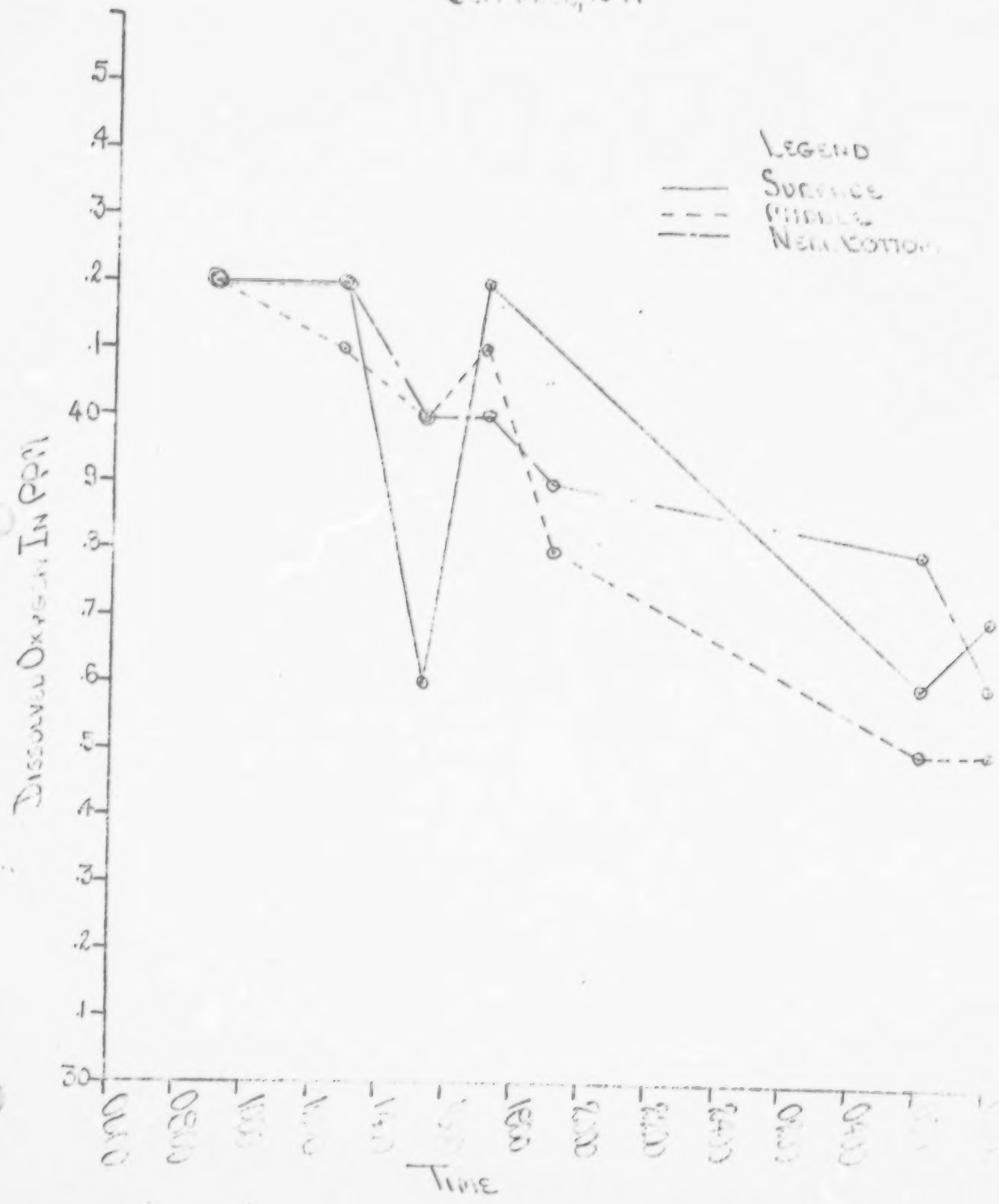


FIGURE 23

TWENTY-FOUR HOUR [illegible] OXYGEN PROFILE AT THE LEFT BANK NEAR POINT OF SIMILAR CROSS-SECTION SEPTEMBER, 1971

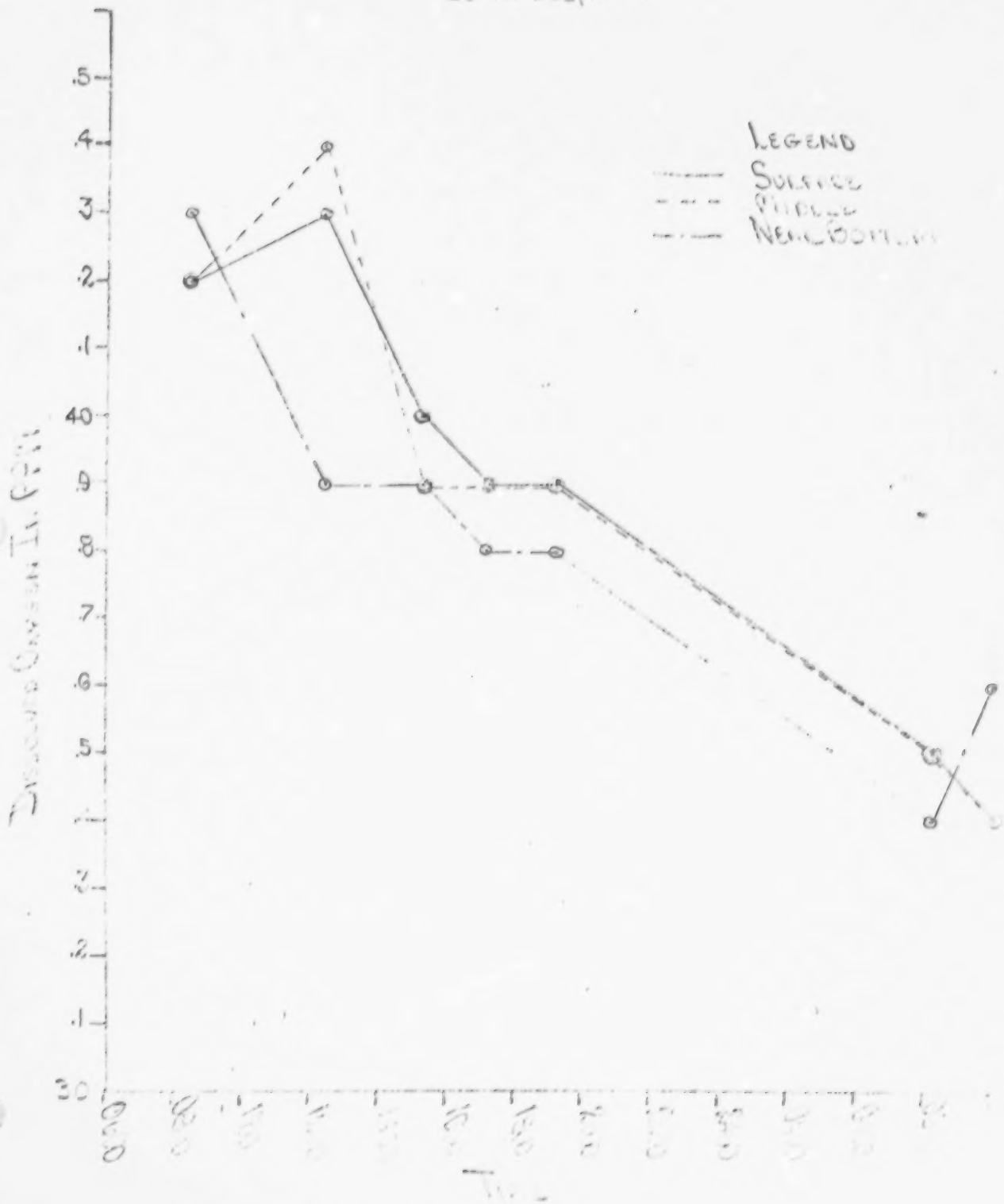


FIGURE 24

TWENTY-FOUR HOUR DIURNAL OXYGEN PROFILE AT THE RIGHT JUNCTION POINT OF STATION CR 1102.7

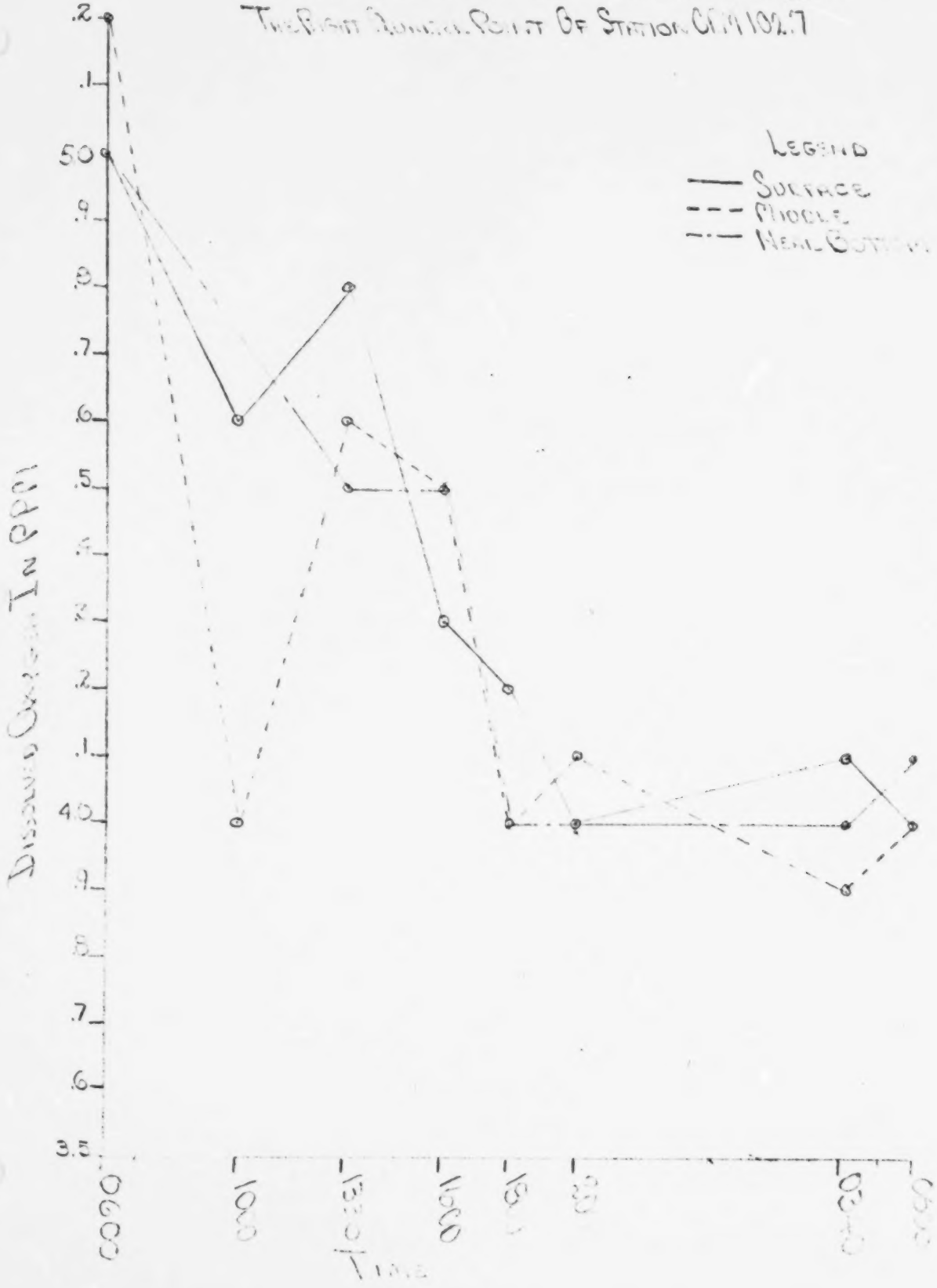


FIGURE 25

TWENTY-FOUR HOUR DISSOLVED OXYGEN PROFILES
AT MID CHANNEL OF STATION CRM 132.7
SEPTEMBER, 1971

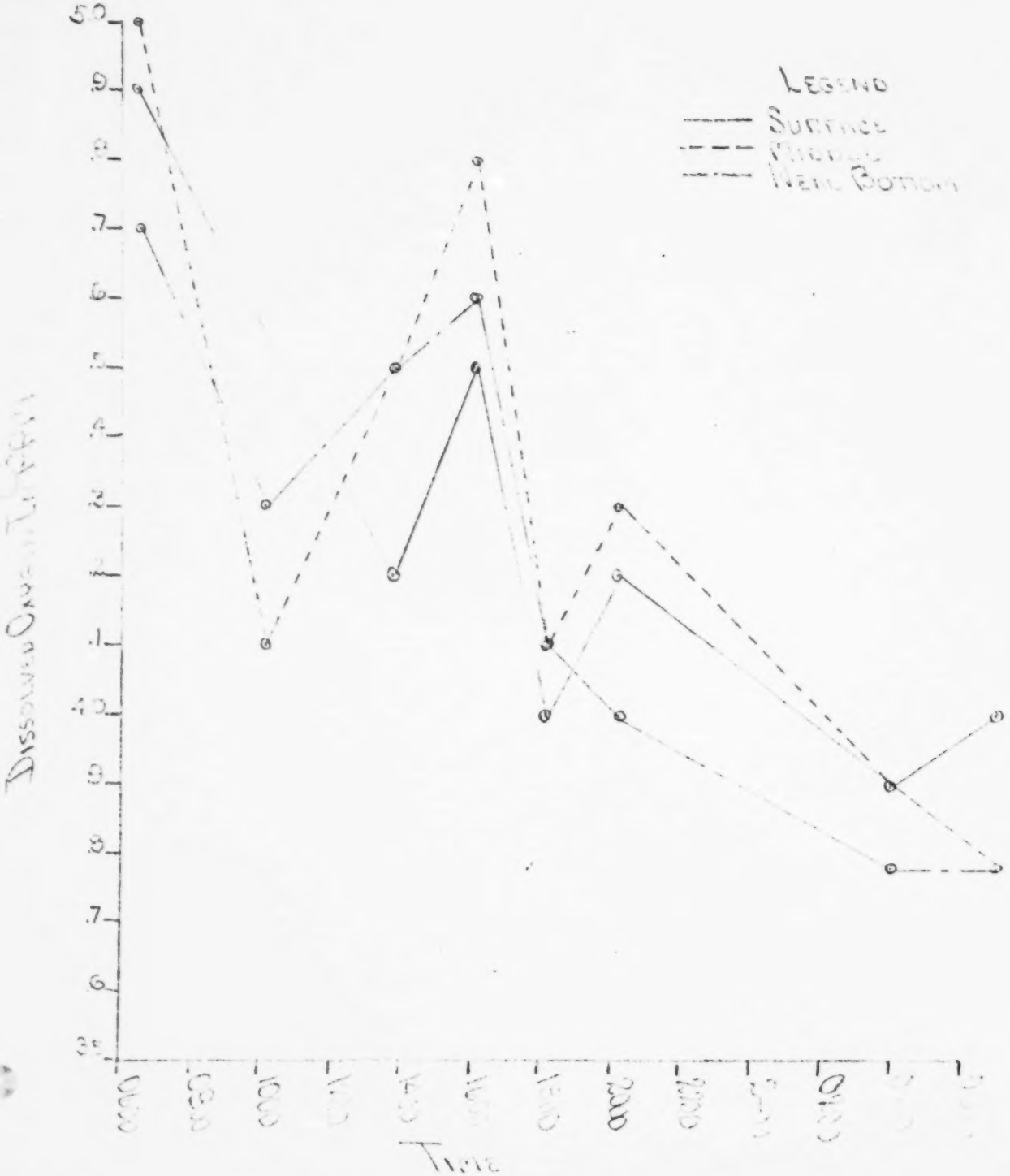


FIGURE 26

TWENTY-FOUR HOUR [illegible] DISSOLVED OXYGEN PROFILES AT THE LEFT QUARTER POINT OF STATION CP-1 [illegible] SEPTEMBER, 1971

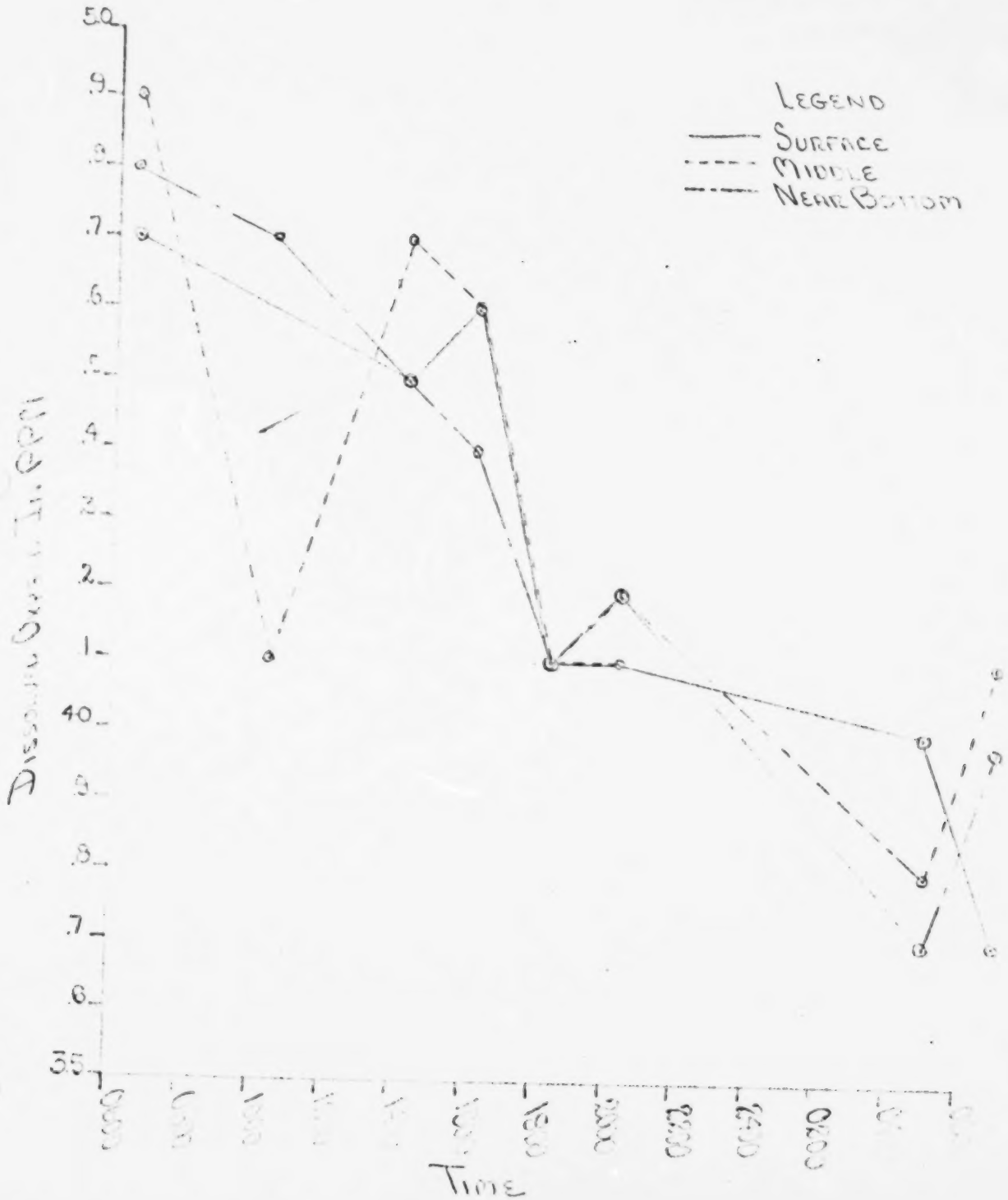


FIGURE 27
MEAN AND CONFIDENCE INTERVALS (0.05 LEVEL)
FOR TOTAL PHYTOPLANKTON COUNTS, SEPTEMBER

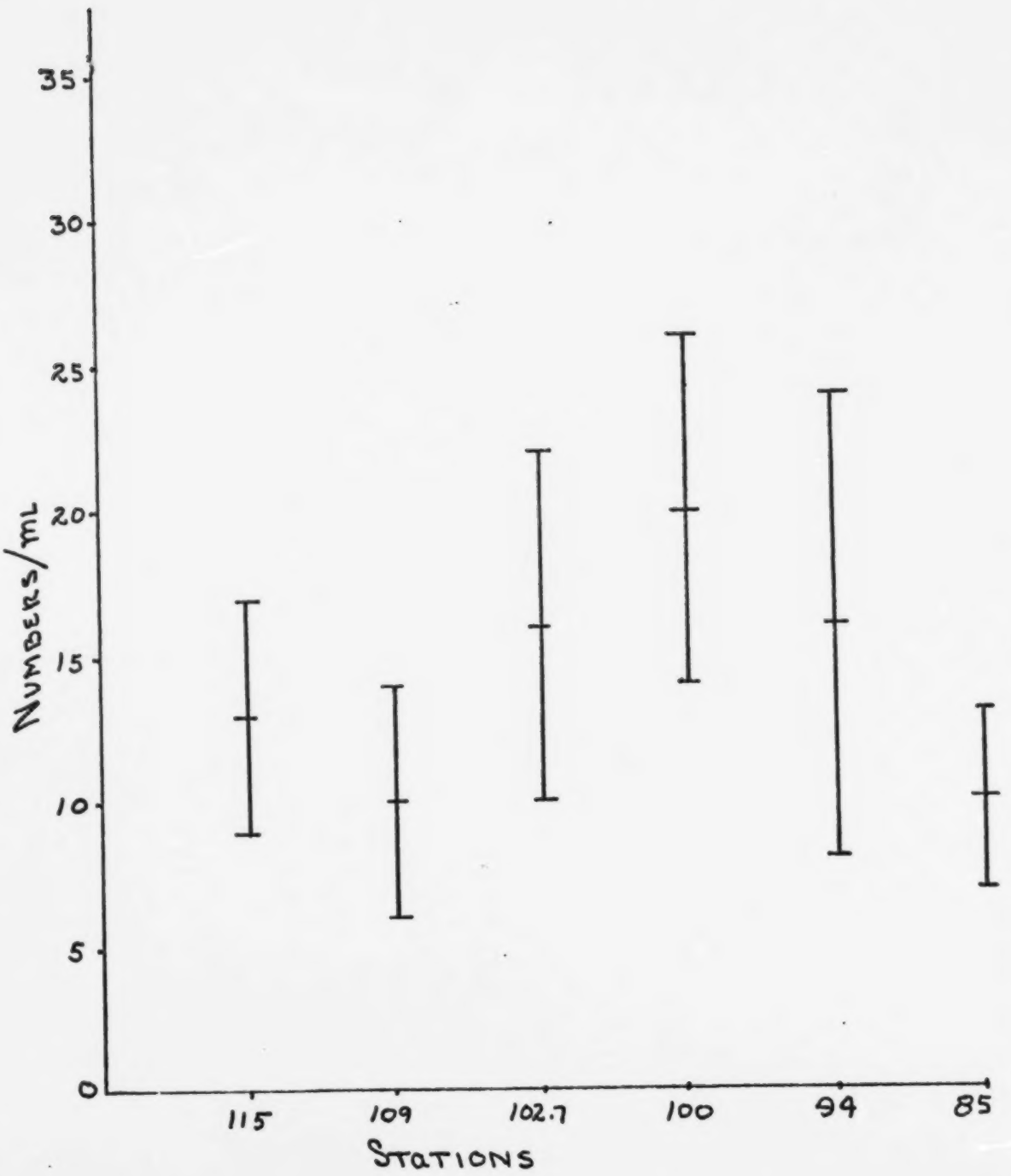


FIGURE 28
MEAN AND CONFIDENCE INTERVALS (0.95 LEVEL)
FOR TOTAL PERIPHYTON COUNTS, SEPTEMBER

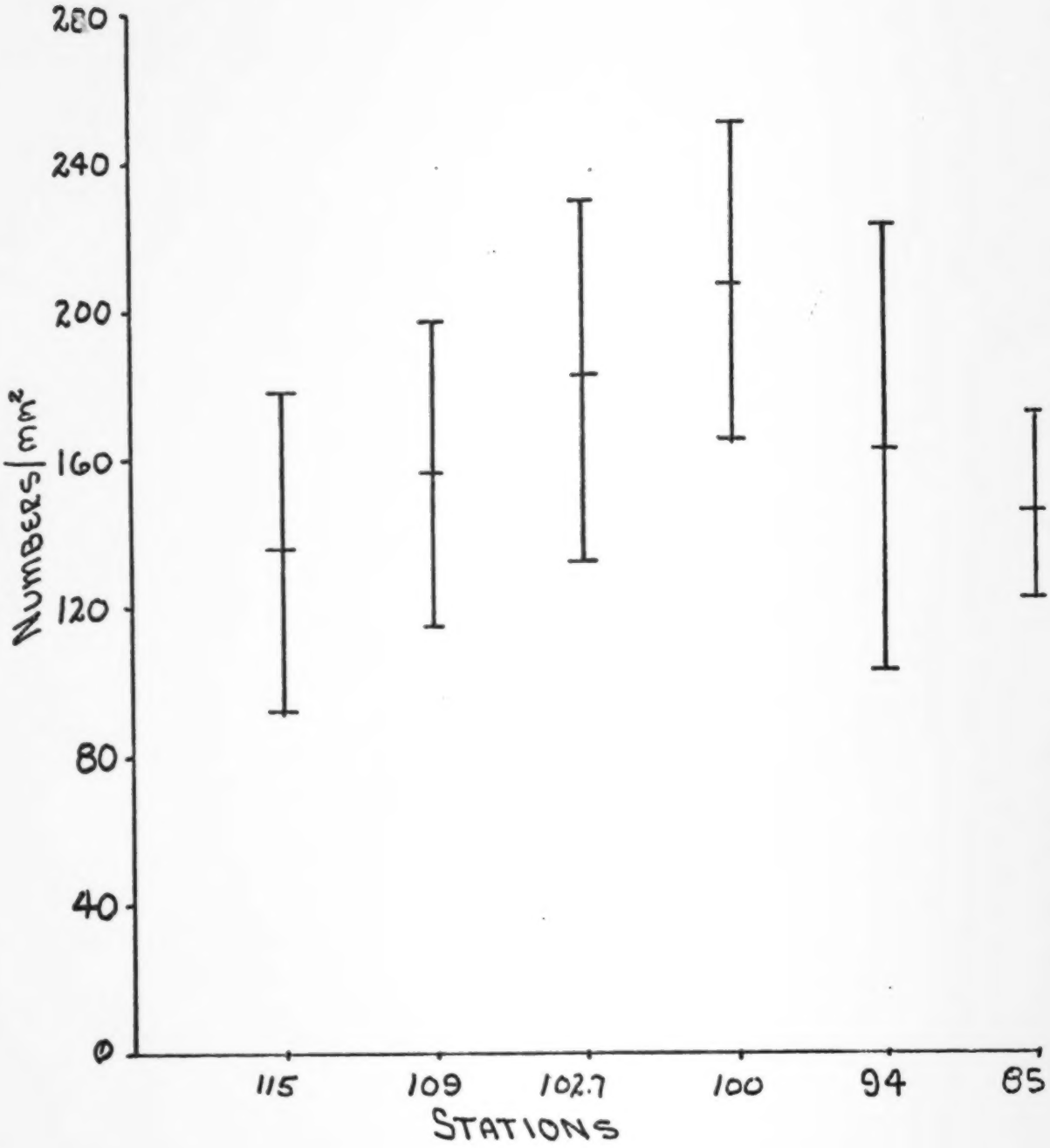


FIGURE 29
MEAN AND CONFIDENCE INTERVALS (0.05 LEVEL)
FOR TOTAL PERIPHYTON COUNTS, JANUARY

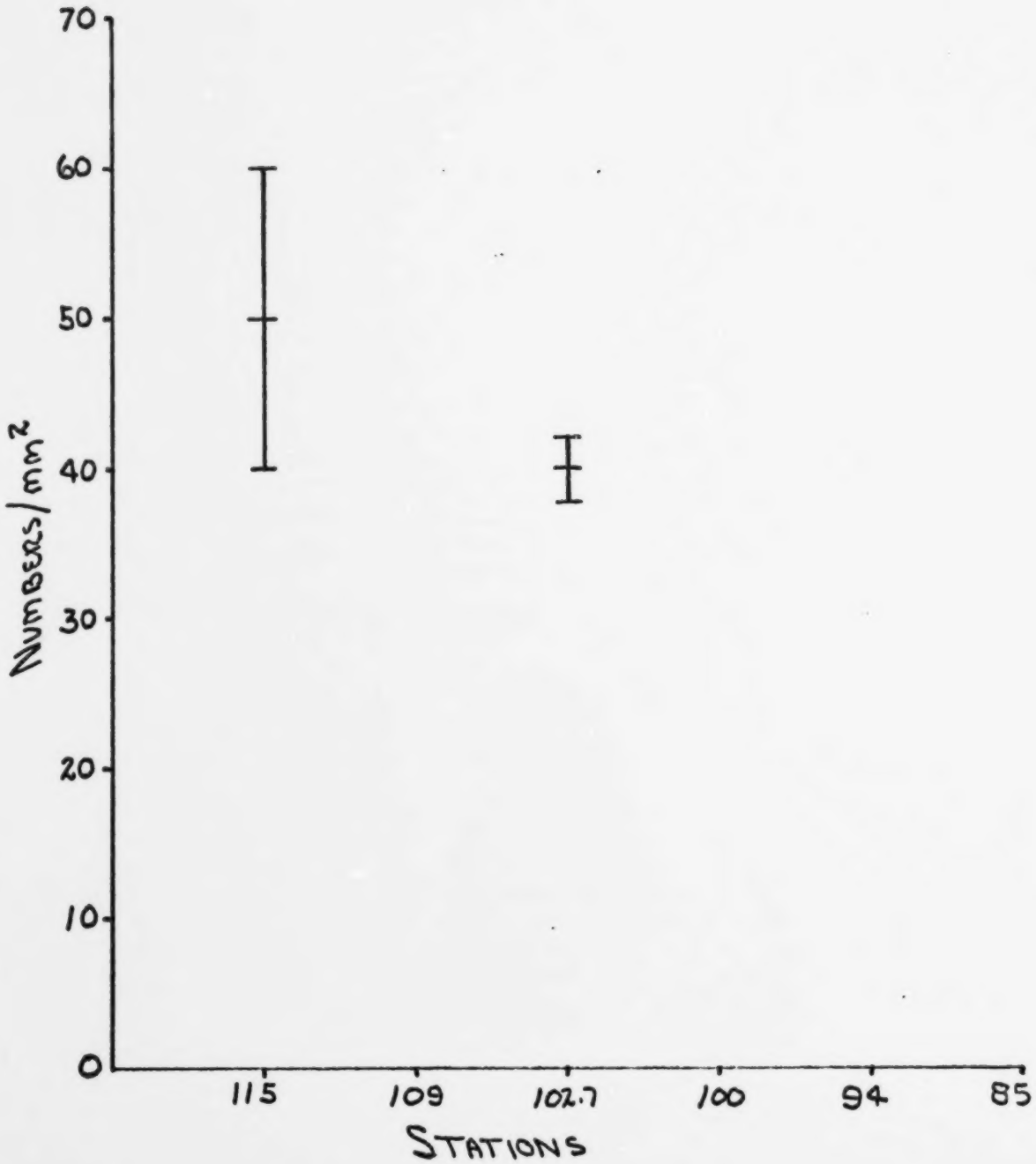


FIGURE 30

MEAN AND CONFIDENCE INTERVALS (0.05 LEVEL)
FOR PERIPHYTON AUTOTROPHIC INDEX, SEPTEMBER

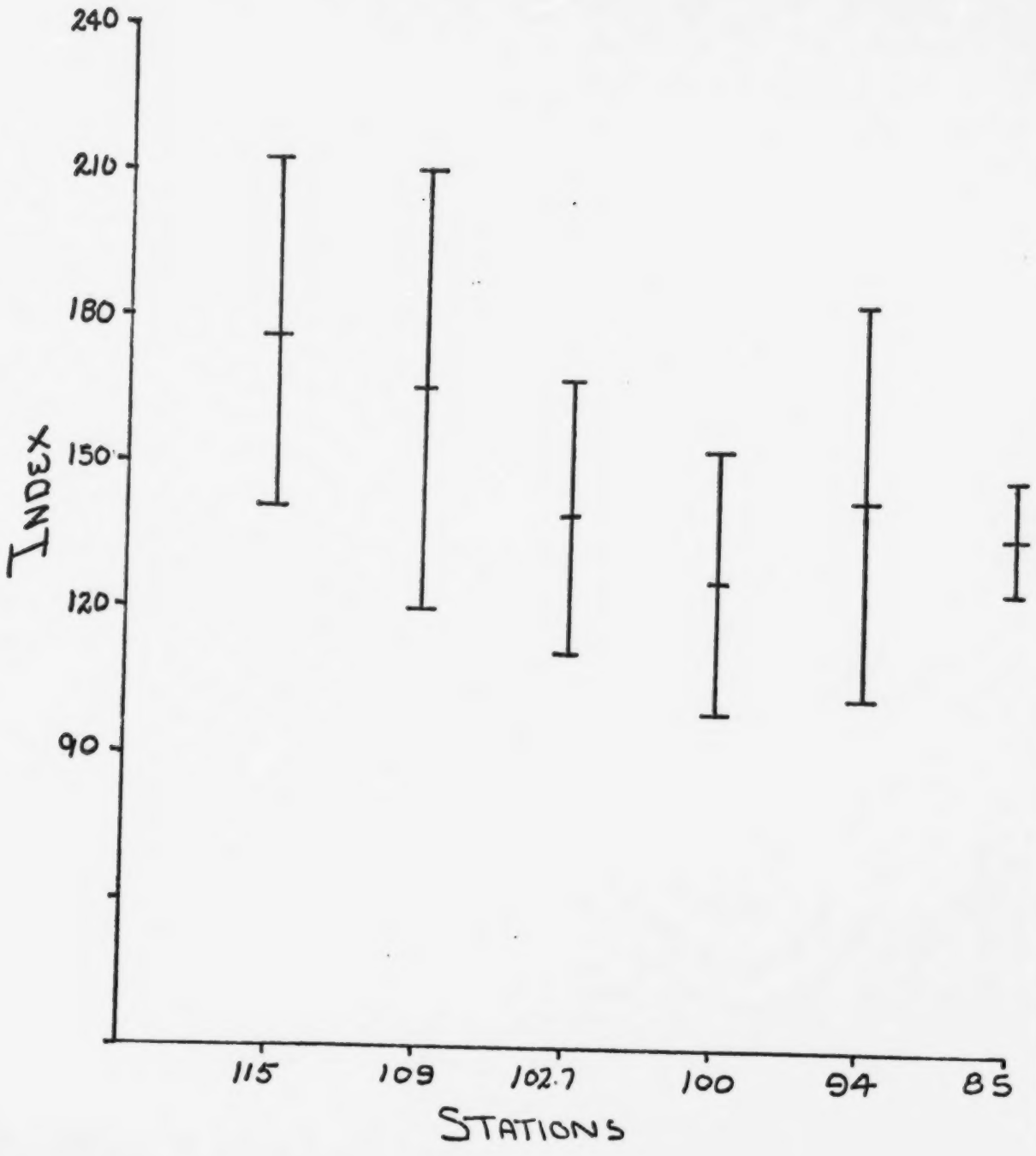


FIGURE 31

MEAN AND CONFIDENCE INTERVALS (.005 LEVEL)
FOR PERIPHYTON AUTOTROPHIC INDEX, JANUARY

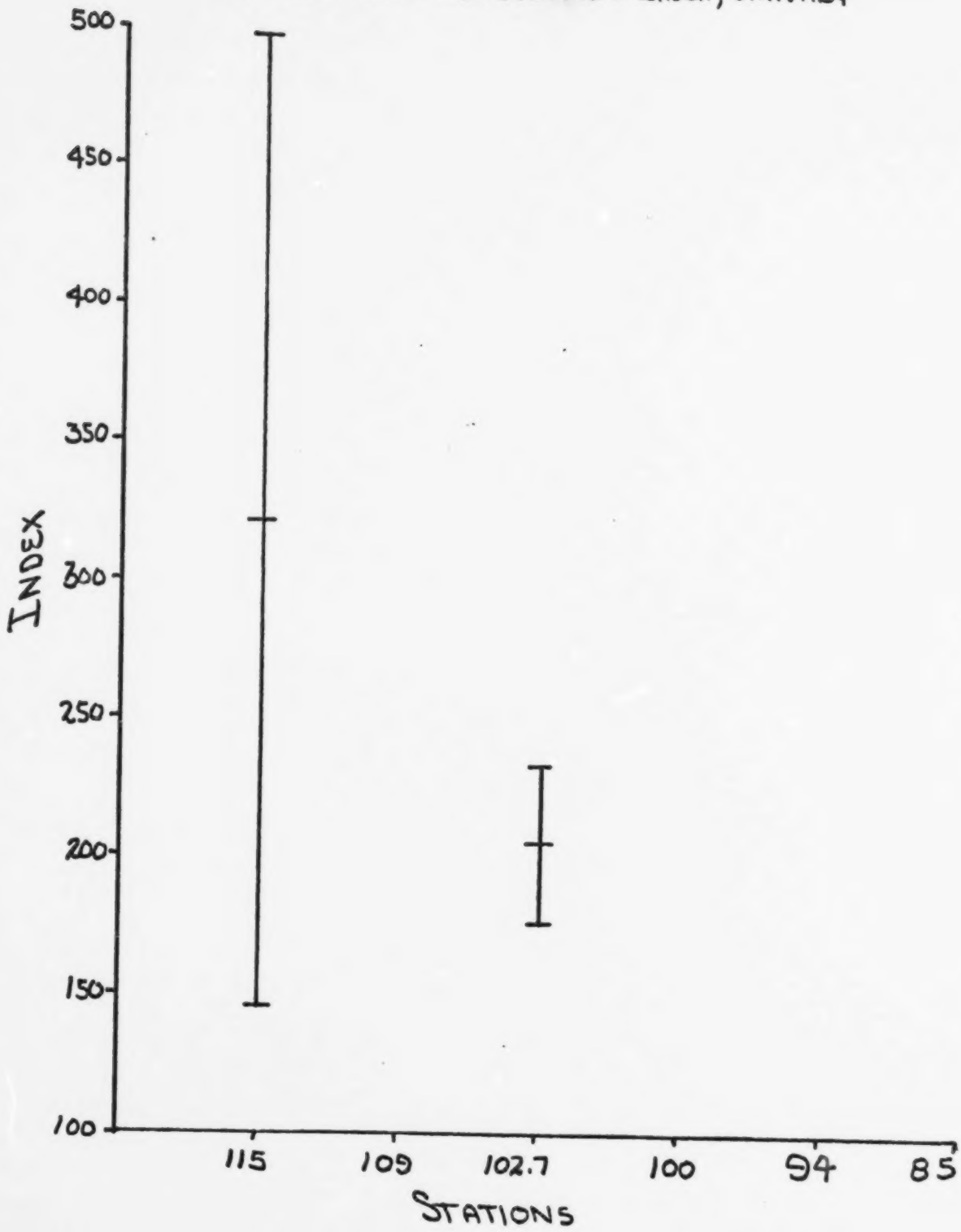


FIGURE 32
MEAN AND CONFIDENCE INTERVALS (0.05 LEVEL)
FOR PERIPHYTON DIATOM MEAN DIVERSITY (J)
SEPTEMBER

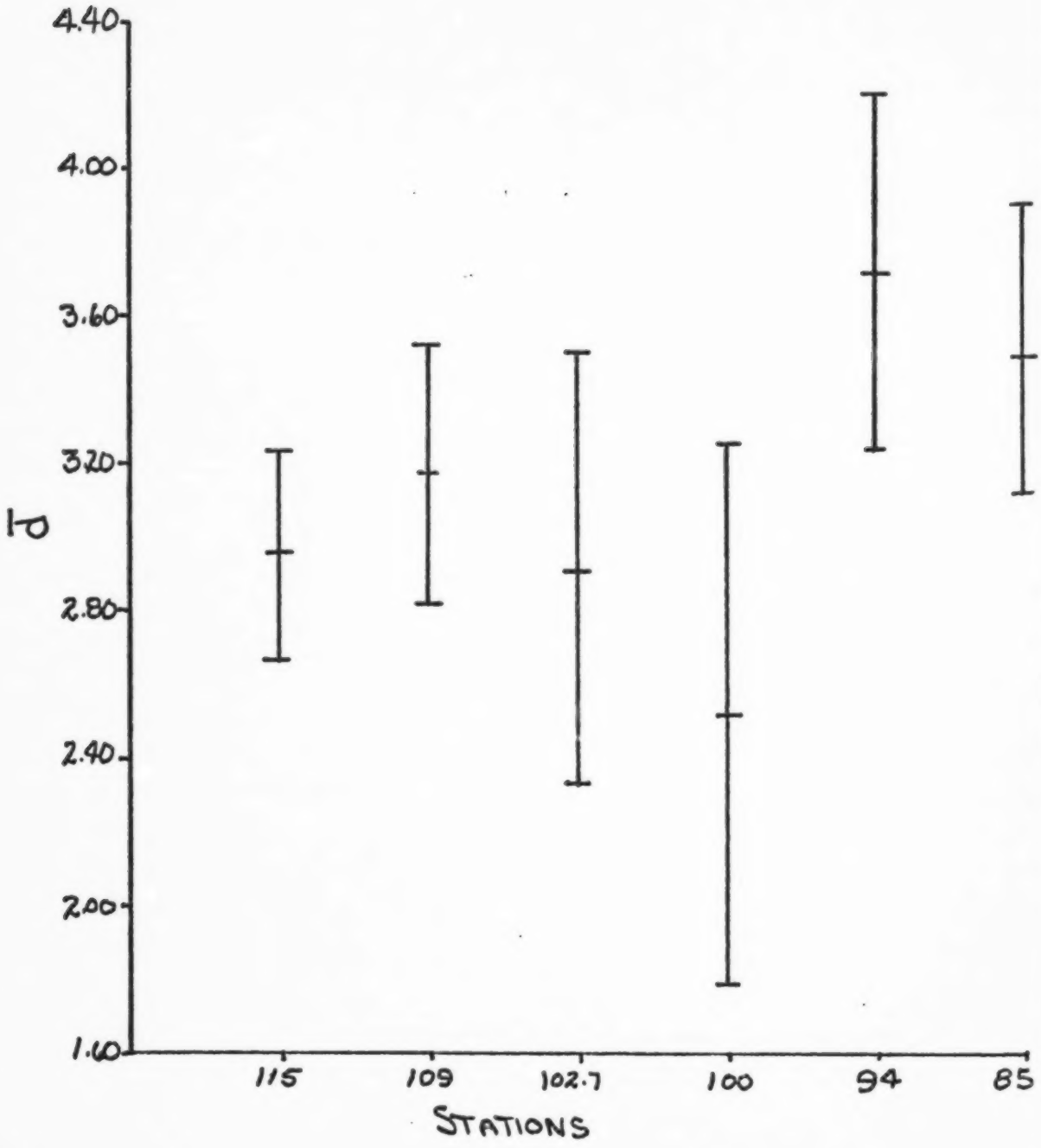


FIGURE 33
MEAN AND CONFIDENCE INTERVALS (0.05 LEVEL)
FOR PERIPHYTON DIATOM MEAN DIVERSITY (d)
JANUARY

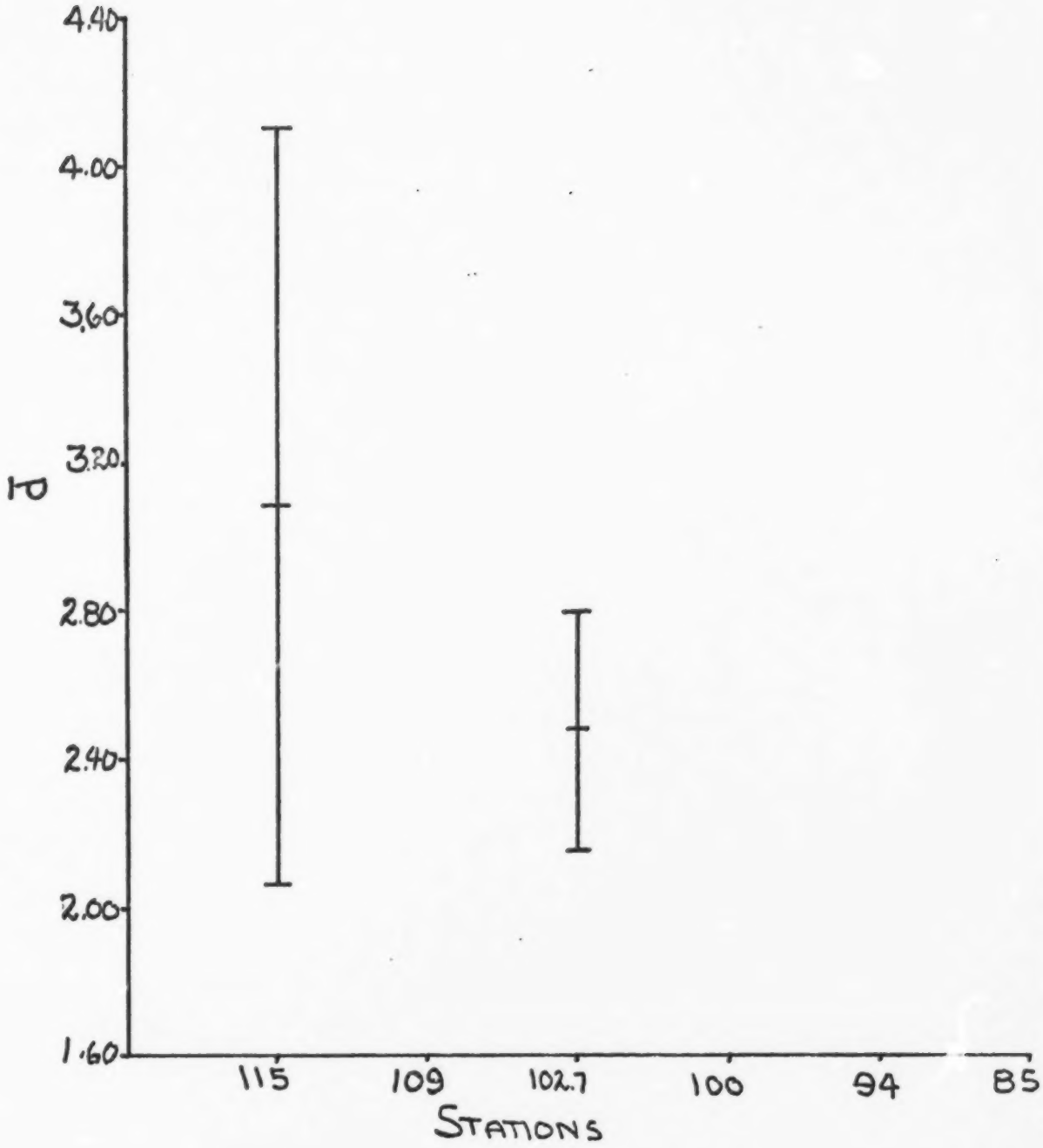


FIGURE 34
MEAN AND CONFIDENCE INTERVALS (0.05 LEVEL)
FOR PERIPHYTON DIATOM EQUITABILITY (e)
SEPTEMBER

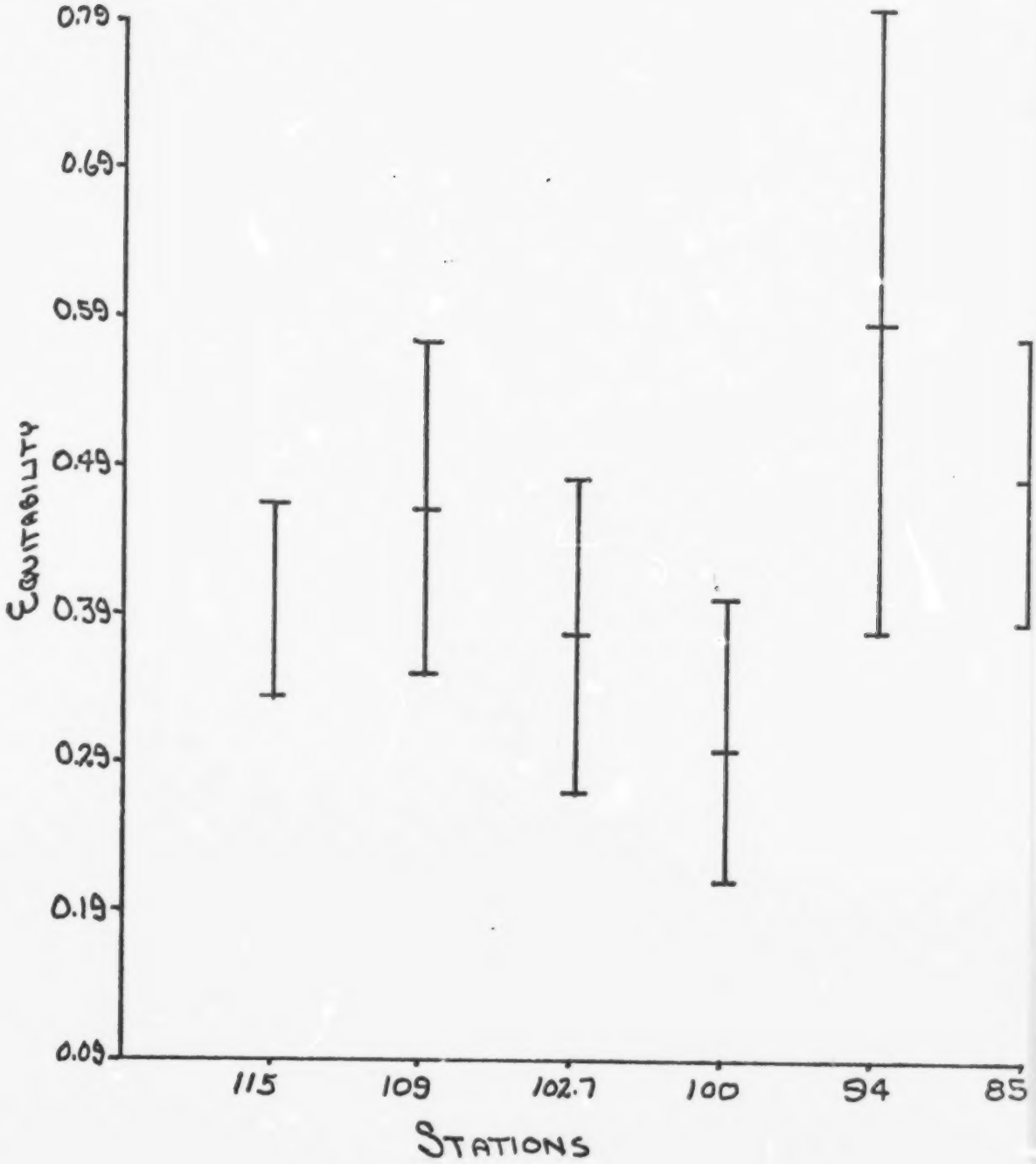
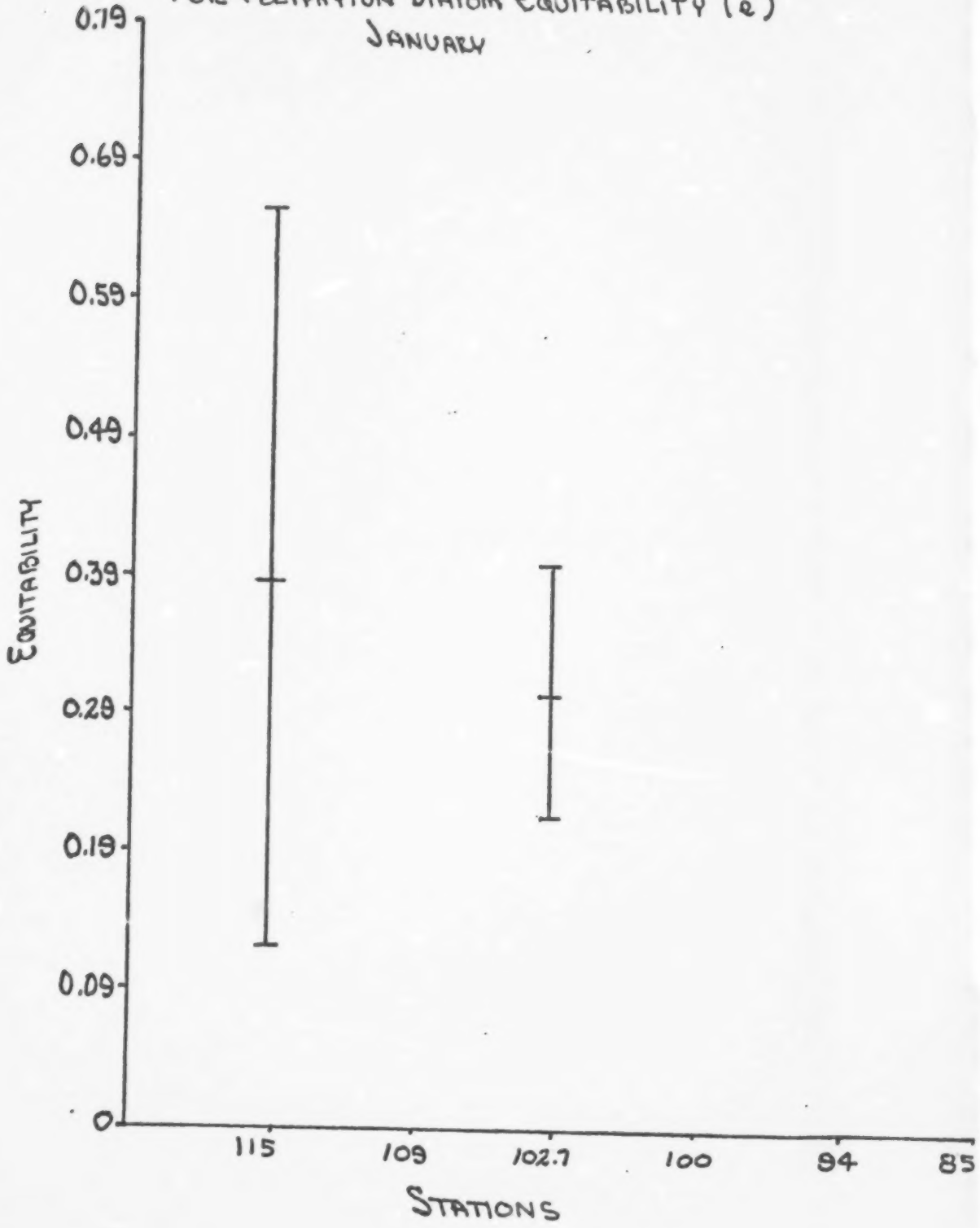


FIGURE 35

MEAN AND CONFIDENCE INTERVALS (0.05 LEVEL) FOR PERIPHYTON DIATOM EQUITABILITY (e) JANUARY



APPENDICES

Appendix A

FIELD METHODS

Chemical

1. Dissolved oxygen conditions were determined at Stations CRM-109 and CRM-103 during one 24-hour period. Samples were collected at intervals of approximately 2 hours and dissolved oxygen content determined immediately using a modified Winkler method. Samples were collected from the middle and quarter point on the horizontal plane and near-surface, middle, and near-bottom on the vertical.

Physical

1. Light transmission data (percent transmission) was collected from the middle of the river at Stations CRM-115 and CRM-102.7. These data were collected with a submarine photometer during the middle of the day under constant light conditions.
2. Temperature data were collected from the following eight stations: CRM-115, CRM-109, CRM-106, CRM-103, CRM-102.7, CRM-100, CRM-97, and CRM-94. Sampling points were at mid-river and quarter points at the following depths: near surface, 0.3 meter, 0.9 meter, and then at 0.6-meter intervals to near the bottom. This temperature profile was established one time during each sampling trip.

Biological

1. Periphyton samples were collected by four diatometers, two on each side of the river, each with eight slides (1 inch by 3 inches), placed at each station. Eight slides per river bank were collected at random from the total 16 slides. Of these, four were used for identification and counts, and four were used for chlorophyll and dry-weight analyses.

All diatometers were anchored separately to help reduce missing data problems and remained in the river for 3 weeks before the slides were collected. Qualitative natural periphyton-benthic samples were collected from a variety of habitats at each station when the slides were being placed in the river and retrieved. Laboratory methods follow in Appendix B.

2. Phytoplankton grab samples were collected when the diatometers were placed in the river. Three surficial samples were collected at each of the diatometer sites. In addition, three replicate samples were collected in the middle of the river at depths of 0, 3, 6, and 9 meters and just above the bottom. All grab samples were collected with a Kemmerer water sampler. Description of laboratory analyses is given in Appendix B.

3. Macrobenthos Ponar samples were collected in triplicate from the productive overbank area on each side of the river at each station. Each sample was washed through a No. 30 screen; and the remains were placed into a jar, fixed with 70 percent alcohol, and returned to the laboratory for further analysis. Qualitative benthic samples were collected for a period of 30 minutes at each station using dip nets, dredges, and hand picking. These samples were preserved and returned to the laboratory, where they were sorted and identified.

4. Fish samples were collected with an electric shocking device from all six stations. Three replicate half-hour collections were made on each side of the river during both daytime and nighttime periods. The animals collected were identified to species, weighed, and measured. The large and/or easily identified fish were processed in the field, while

those which required greater effort were fixed in 10 percent formalin and returned to the laboratory for further processing.

Appendix B

PROCEDURES FOR PLANKTON AND PERIPHYTON COLLECTION AND ANALYSIS

PLANKTON PROCEDURES

I. Field.

A. Collect a minimum of three replicates at various depths with a Kemmerer or Van Dorn bottle.

B. Place the sample in a 2-liter polyethylene container which contains 200 ml of merthiolate preservative.

C. Keep samples in a cool dark container.

D. Tag the sample and fill out forms properly.

E. Return to laboratory.

F. Secure the sample in designated areas.

II. Laboratory.

A. Calibration of Sedgwick-Rafter cell.

1. Measure the height of the glass (10 readings) and the height of the glass plus brass (10 readings) with a micrometer.

2. Subtract the averages and record the depth of the cell in mm.

3. Measure the length of the cell with the calipers.

4. Calibrate the width of your eyepiece Whipple grid with a stage micrometer according to Standard Methods. Use 10X eyepieces and 20X objectives.

5. Calibrate the volume of one strip.

Example: (length of cell in mm)(depth of cell in mm)

(whipple width in mm) = vol. of one strip in mm^3

$(50.4)(0.3)(0.4) = 60.4\ mm^3$

6. Enumeration factor:

For one strip = $\frac{1{,}000\ mm^3}{60.4\ mm^3} = 16.6 \times 1/10^* = 1.66 + 16.6 = 18.3$

For two strips = $\frac{18.3}{2} = 9.2$

For three strips = $\frac{18.3}{3} = 6.7$

* 1/10 is the dilution factor in the sample (100 ml preservative diluted to 1,000 ml with sample.)

7. Number per ml = actual count X enumeration factor.

B. Sedgwick-Rafter Counts.

1. Shake the sample vigrously 10 times.

2. Remove approximately 1 ml with a pipet or eye dropper and place it in the S-R cell. (Refer to Standard Methods pages 734-735 for technique.)

3. Wait 15 minutes.

4. Count two strips.

5. If you find less than 100 algae, count three strips.

6. Use the clump count method. Count isolated cells and each natural colony of cells.

7. It is important to adopt a consistent system of counting organisms that lie partially within the grid or which touch one of the edges. We will count organisms that are one-half or more within the grid.

8. Calculate number pe ml.

C. Alternate Methods or Special Studies.

1. Species Diversity Studies.

a. Count and identify 500 to 1,000 organisms to species.

b. Enumeration factor: $\frac{1{,}000\ mm^3}{\text{vol. of "strips" counted in } mm^3}$ X dilution factor

c. Number per ml = actual count X enumeration factor.

d. If the organisms are sparse, concentrate them.

e. Centrifuge at 5,000 g's for 20 minutes.

f. Number per ml for original sample =

Number per ml X $\frac{\text{vol. concentrate}}{\text{original vol.}}$

g. If two species are difficult to distinguish at 200X, do a proportional count of 100 organisms of that genus at 1,000X and convert your totals based on a proportional count.

Example: Find 100/ml Cyclotella in a S-R cell.
Find 70% under 1,000X are C. cryptica and 30% are C. comta.
(100)(.70) = 70/ml C. cryptica
(100)(.30) = 30/ml C. comta

h. If you are unfamiliar with a set of samples, you will probably have to look at and identify many of the organisms to species before you do the S-R count.

i. Count live and dead pennates and centrics.

j. Try to identify as many live diatoms to species as possible. Use the above approach or look at Hyrax slides of the species.

2. Volumetric Analyses.

(See Standard Methods page 735.)

D. Dry and Ash-Free Weight.

1. Wash sample with several volumes of distilled water by centrifugation (5,000 g's for 20 minutes) to reduce the amount of contamination by dissolved solids. After washing, concentrate the sample by centrifugation.

2. Filter the sample at 9.8 inches of vacuum through a 0.45 μ Millipore filter which has been weighed previous to filtration.

a. If you want to weigh dissolved solids, place the filtrate in a separate crucible, wash the filtrate vessel three times, and pour the contents into the crucible.

b. Place filter in another crucible.

NOTE: All crucibles should be cleaned according to standard procedures, dried, ashed at 500°C. for ½ hour, cooled in dessicator (approximately 1 hour), and weighed. Never touch crucibles with your hands after they have been ashed.

3. Place the tared porcelain crucible in the oven.

4. Dry to a constant weight at 105°C. for 24 hours.

5. Cool in a dessicator for 1 hour.

6. Subtract weight of crucible to obtain dry weight.

7. After the dry weight is determined, place crucible in muffle furnace at 500°C. for 1 hour.

8. Cool in dessicator for 1 hour.

9. Rewet ash with distilled water.

10. Bring to constant weight (24 hours) at 105°C.

11. Subtract weight of crucible to obtain ash weight.

12. Subtract ash weight from dry weight to obtain ash-free weight.

PERIPHYTON PROCEDURES

Genera and Species Identification

I. Field

A. Place eight clean slides in the diatometer and allow them to remain in a habitat for a predetermined time (two to six weeks).

B. Collect four of the slides from the diatometer with forceps.

C. Place each slide in a separate amber bottle.

D. Preserve with 6-3-1 formalin or methiolate (10 to 20 ml).

E. Refrigerate if you want to look at live material.

F. Make sure bottles are labeled properly with tags.

II. Laboratory

A. Scrape both sides of slide with razor blace.

B. Wash as you scrape with distilled water.

C. Dilute with an appropriate volume of distilled water.

D. Measure slide dimensions in mm and convert to mm^2.

E. Record volume.

F. Use for S-R and Hyrax slides.

G. Incineration method and diatom counts,

1. Hyrax slides:

a. Mix sample.

b. Place known volume on #1 or #1½ square coverslip with eyedropper

c. Place drops in following order:

1	2
	5
4	3

d. Record volume on slide, number of drops, and the number of the calibrated eyedropper.

e. Dry at 50°C (less than 1 on hotplate) for 30 minutes. If you do not find 16 to 20 cells per field, add more material.

f. Incinerate at 500°C. (HIGH on hotplate) for 30 minutes.

g. Let coverslips cool.

h. Label slides with carbon pencil.

i. Mount with Hyrax.

(1) Place Hyrax on slide.
(2) Allow solvent to evaporate. (Hyrax becomes brittle; it flicks off end of needle.)
(3) Place coverslip on the Hyrax.
(4) Remove slide from hotplate.
(5) Press coverslip down until Hyrax solidifies.

j. Clean Hyrax off of slides with razor blade.

k. Put labels on slides.

2. Identification and enumeration:

a. Calibrate eyepiece micrometer.

b. Measure area of coverslip in mm^2.

c. Count 500 to 1,000 diatoms and identify to species.

d. Do clump count.

e. Circle new species rare species, and unknowns; record coordinates; and photograph.

f. Convert to number per mm^2.

g. Calculation:

$$\frac{(\#\text{ diatoms})(\text{area coverslip})(\text{ml of original concentrate})}{(\text{area counted})(\text{vol. on coverslip})(\text{area of slide scraped})} =$$

$$\text{No./mm}^2 \times 1 \times 10^6 = \text{No./m}^2$$

H. Sedgwick-Rafter Phase.

1. Calibrate S-R length and depth and

2. Width of field and volume of strip.

3. Count and identify 500 to 1,000 other algal cells; note live and dead pennates and centrics. Refer to Plankton Section.

4. S-R strip count calculations:

a. $$\text{No./mm}^2 = \frac{(\#\text{ counted})(\text{S-R factor})(\#\text{ ml diluted})}{\text{area of slide scraped in mm}^2}$$

b. $$\text{No./m}^2 = (\text{No./mm}^2)(1 \times 10^6)$$

I. Dry and Ash-Free Weight.

1. Scrape slides and wash with distilled water or acetone (for chlorophyll analyses) into amber bottles.
2. Measure length and width of slides in millimeters with the calipers.
3. Place 9 to 12 capless amber bottles (samples with 90% acetone) in the National vacuum oven.
4. Dry down to approximately 10 to 12 ml at 50°C. (setting 2.3) and 25 inches of vacuum.

   NOTE: It takes approximately 2 hours to dry 100 ml of 90% acetone.

5. Remove bottles and cap loosely.
6. Place contents in previously cleaned, dried, and weighed porcelain crucibles (100- or 250-ml).
7. Scrub with a rubber policeman and wash sides of bottle.
8. Place crucibles on the stainless steel rack.
9. Dry to a constant weight at 105°C. for 24 hours.
10. Cool in the dessicator for 1 hour.
11. Weigh.
12. Subtract weight of crucible to obtain dry weight.
13. Place rack of crucibles in muffle furnace at 500°C. for ½ hour.
14. Place in the dessicator and cool for 1 hour.
15. Weigh.
16. Rewet ash with distilled water.
17. Dry to a constant weight for 24 hours at 105°C.
18. Place in dessicator and cool for 1 hour.
19. Subtract weight of crucible to obtain ash weight.
20. Subtract ash weight from dry weight to obtain ash-free weight.

CHLOROPHYLLS

I. Introduction

In many cases it is necessary for aquatic biologists, chemists, and engineers to know the total quantity (standing crop) of living plankton or periphyton algae in a particular habitat or community. Wet weight, dry weight, ash-free weight, total organic phosphorus and nitrogen, and total carbon all have been utilized, but they are not specific for the phytoplankton. Cell counts and volume counts of phytoplankton are very popular among aquatic biologists, but they are time consuming and can be used only by experts on algae. Maloney, et al (1962) have utilized the coulter counter to estimate population size of unialgal cultures. This may be adaptable for estimating the phytoplankton in such oligotrophic lakes as some of the Great Lakes. Up to this time it has only been feasible to use it on uni and some mixed cultures. McNabb (1960) devised a method for estimating the phytoplankton crop by means of a membrane filter. This method is not relatively time consuming, but one needs to be properly trained in algal identification. It is obvious that all of these methods have their drawbacks. They are either not specific for algae, they are time consuming, or you need trained personnel to obtain identification.

The chlorophyll method overcomes all of the above-mentioned disadvantages. It is highly specific for algae, takes a small amount of time, and requires little training.

Although chlorophyll concentration varies with species, environmental, and nutritional factors that do not necessarily affect the standing crop; chlorophyll is a useful estimate of the algal biomass and is an indication of the nutrient content, organotrophic status, and/or toxicity of the water.

Algae contain approximately 1 to 2% chlorophyll by dry weight. If dissolved and/or particulate degradable organic matter is present in high concentrations, large populations of filamentous bacteria, stalked protozoa, and other non-chlorophyllous micro-organisms develop, causing a reduction in the percentage of chlorophyll a. If the biomass (organic matter) chlorophyll relationship is expressed as a ratio (autotrophic index), values greater than 100 may be due to organic pollution (Weber and McFarland, 1969).

Information on the physiological condition (or health) of the algal population can be obtained by measuring the amount of pheophytin a, a physiologically inactive degradation product of chlorophyll a; and under severe environmental conditions it may be responsible for most, if not all, of the OD 663 in the acetone extract. The presence of relatively large amounts of pheophytin a is an abnormal condition indicative of water quality degradation.

II. Methods.

A. Plankton.

1. Field.

a. Collect samples with a Van Dorn or Kemmerer water sampler.

b. Place the sample in a 2-liter polyethylene container. Do not preserve.

c. Immediately refrigerate at 4°C in the dark.

d. Immediately after returning from the field, process the sample in dim light.

e. Filtration.

(1) Use 0.45 μ pore size M.F. or glass fiber filter.
(2) If dry weights are to be performed, weigh filters before use.
(3) Place a pinch of $MgCO_3$ on the filter (.10 mg/cm^2 gives sufficient coverage).
(4) Wet with distilled water to evenly distribute $MgCO_3$ over filter.
(5) Mix and filter (use volumetric pipet) a known amount of sample.
(6) Wash pipet and funnel with distilled water and filter washings.
(7) Record amount of sample filtered. The amount of sample filtered will vary with conditions, but filter until nice green or brown color appears and filtration slows down.
(8) Use a suction of 2/3 atmosphere (9.8 psi) or less.
(9) Suck filter as dry as possible after filtration (approximately 30 seconds).
(10) Place filter in previously refrigerated Kimble #1,24 size darkened vials.
(11) Place information tag on vial.
(12) Place sample in dry ice container and ship back to laboratory.

f. If it is not possible to filter in the field, send refrigerated samples back to the main laboratory for immediate filtration and storage. Steps e.(1)-(12) can be performed on a boat if adequate room is available with the use of a hand suction pump.

2. Laboratory.

a. Place vials with filters in the dark and freeze at -20°C.

b. Extract chlorophyll within one week if possible.

c. Extraction should take place in a cool, dimly lighted room.

d. Place filter in mechanical grinding vessel.

e. Add 2 to 5 ml of 90% acetone (90 ml acetone to 10 ml saturated $CaCO_3$ solution) to grinding vessel.

f. Grind at least 1 to 2 minutes.

g. You may want to add ground glass to facilitate grinding and tissue disruption.

h. Transfer sample to a stoppered (rubber, teflon, or silicone stopper) centrifuge tube.

i. Wash grinding vessel three times with 90% acetone.

j. Bring volume up to 10 ml or some convenient volume with 90% acetone.

k. Steep at 4°C for 24 hours in the dark.

l. Agitate twice during the extraction period.

m. The extract is clarified by centrifuging 20 minutes (9,500 rpm) in the refrigerated centrifuge.

n. Determine amount of chlorophyll on the P & E 202 recording spectrophotometer

o. Leave samples in dark until you are ready to read them on the spectrophotometer.

3. Spectrophotometric analysis - Trichromatic method.

a. Operating procedure for Perkin-Elmer 202:

(1) Turn the main power switch to ON and the STDBY-NOR switch to NOR.
(2) Insert chart paper (350-750 mμ).

(a) Lift pen from chart paper.
(b) Turn scanning switch to RESET position.
(c) Hold the chart drum firmly and remove it from the instrument by lifting the drum straight up.
(d) Press down on one end of the curved lever at the top of the chart drum.
(e) Slide the paper under the paper holder and align the paper and drum index lines.
(f) Wrap the chart paper around the drum and press the opposite end of the curved lever at the top of the drum.

(g) Insert the remaining edge of the paper under the raised edge of the paper holder.
(h) Check the paper index mark (middle of first hole) for proper alignment and make certain that the top of the chart paper is flush against the upper lip of the drum.
(i) Set the 12-position selector on the base of the drum to the N position.
(j) Install drum on instrument (check wavelength and pen alignment).
(k) With the scanning switch in the RESET position, manually rotate the drum to the beginning of the wavelength region to be scanned.

(3) To change from UV to VIS (visible) range, set the scanning switch to RESET.
(4) Manually rotate the chart drum in a clockwise direction until the metal paper holder on the drum passes the wavelength indicator. A definite click will be heard. The VIS indicator will light.
(5) Set the SLIT override control at 25.
(6) Gain adjustment. The GAIN CONTROL located on the side panel of the instrument should be adjusted so that there is neither "dead spot" nor overshoot in the pen response.

(a) Insert into the sample beam the Holium glass.
(b) Shut and lock the door of the instrument sample compartment.
(c) Set the pen on the paper.
(d) Turn the scanning switch to the SLOW position and run the spectrum.
(e) When the spectrum has been completed, turn the scanning switch to RESET.
(f) Manually turn the drum to a section of the spectrum where a deep absorbance band occurs, e.g. 450 mμ in the VIS range with Holium glass.
(g) Turn the drum back just far enough to allow the pen to rise rapidly as it follows the spectrum.
(h) The pen should follow the spectrum with an overshot of no more than 0.2 absorbance units and with no sluggish movement of the pen.

(1) Overshoot correction is found on page 14, Section III.D.2. of the P & E Manual.
(2) "Dead spot" or sluggishness correction is found on page 14, Section III.D.2. of the P & E Manual.

(7) Balance adjustment - If the gain is changed, the pen balance must be checked.

(a) Turn the drum to a section of the spectrum where the pen indicates about 1.0 absorbance.

(b) Turn the scanning switch to the STOP position and turn the sample compartment door lock to the OPEN position.
(c) Scan the spectral region at SLOW speed. During scanning, the pen should remain steady or should drift less than 0.30 absorbance units per minute.
(d) Adjust the balance control on the side instrument panel until the proper balance is obtained.

(8) Slit override adjustment.

(a) When operating under normal conditions, the slit override control should be set at 25. It should be adjusted only when the AGC meter registers full scale (total AGC being used). The slit override adjustment then should be opened only to the point at which the AGC meter registers no more than about 85 at any point in the portion of the spectrum being studied.

(b) Adjustment of the slit override is found on page 15, Section III.D.5. of the P & E Manual.

(9) Zero absorbance adjustment - After adjusting the slit override, the GAIN, and BALANCE controls; the pen must be set for zero absorbance.

(a) Remove any sample from the sample compartment.
(b) Close and lock the sample compartment door.
(c) Using the ZERO adjust knob, bring the pen to zero absorbance units.

(10) Scanning - The instrument is ready for automatic scanning in either range after the above adjustments have been made.
(11) I_o line zero absorbance.

(a) Install a fresh sheet of chart paper for the required range.
(b) Set the scanning switch to RESET and manually turn the drum to the beginning of the wavelength range.
(c) With the sample removed from the sample beam, shut and lock the sample compartment door.
(d) Push the pen against the paper.
(e) Set the scanning switch to either the FAST or SLOW position and record the I_o line. The instrument will stop automatically at the end of the wavelength range.
(f) Set the scanning switch to RESET and return the drum to the beginning of the wavelength range.

b. Spectrum of the sample.

(1) Unlock and open the sample compartment door.
(2) Using a small 2- to 3-ml pipet, place the sample into a 1-cm cuvette (marked RLR) and cap it.
(3) Pour 90% acetone into another cuvette (marked RLR Blank) and cap it.
(4) Insert the sample into the sample beam.
(5) Insert the sample solvent (90% acetone) into the reference beam in back of the sample beam.
(6) Shut and lock the sample compartment door.
(7) With the scanning switch set to the RESET position, make certain the drum is set at the desired wavelength region.
(8) Push the pen against the paper.
(9) Set the scanning switch to SLOW.
(10) The instrument will automatically record the absorbance spectrum of the sample (attached examples).
(11) After spectrum at 750 mμ is recorded, switch to STOP.
(12) Add one drop of 2 N HCL to sample and rescan on the spectrophotometer.
(13) Retrieve the sample and place it in a crucible if dry weights are to be determined.
(14) Wash the cuvette with 90% acetone and place this in the crucible or a waste basin.
(15) Remove chart for permanent record.
(16) Rinse cuvette once with acetone and once with the sample.
(17) Place sample in cuvette and repeat above steps for the next sample.

c. Calculations.

(1) Insert the optical density readings at given wavelengths into the UNESCO equations (attached sheet):

Example: $OD_{663} = 0.801$
$-OD_{750} = \underline{0.001}$

Corrected $OD_{663} = 0.800$

(2) Readings taken at 750 mμ are used to correct for turbidity of the extract. This reading should be subtracted from OD readings at 663, 645, and 630 mμ.
(3) Mg/l in original sample =

$$\frac{\text{(extract (mg/l) concentration) (liters of acetone used)}}{\text{liters of water filtered}}$$

(4) $Mg/m^3 = \frac{\text{(extract conc.)(vol. of extract in liters)}}{\text{vol. of grab sample } (m^3)}$

(5) Record all data on data sheets (attached).

B. Periphyton.

1. Field.

   a. Place eight clean slides in the Diatometer and allow them to set in a habitat for a predetermined time (2 to 6 weeks).

   b. Collect or extract four of the slides from the Diatometer with forceps.

   c. Place each slide in an amber pill bottle that has been previously chilled in dry ice.

   d. Place the information tag on the bottle.

   e. Place the sample in the dark with dry ice.

   f. Bring back to laboratory and freeze at -20°C.

2. Laboratory.

   a. Fill out data sheet (attached).

   b. Thaw samples at room temperature in the dark.

   c. Scrape both sides of slide with a razor blade.

   d. Wash slide with 90% acetone.

   e. Pour contents into a grinding vessel or vessels.

   f. Wash bottle and pour washings into grinding vessel.

   g. Grind for 1 minute.

      NOTE: You may want to use glass to facilitate cell fractionation.

   h. Pour contents back into sample bottle and dilute to 20, 50, or 100 ml with 90% acetone.

   i. Steep for 24 hours at 4°C.

   j. Mix well.

   k. Extract 10 ml with a volumetric pipet.

   l. Cap test tube.

   m. Centrifuge at 9,500 rpm at 4°C for 20 minutes.

   n. Follow Section II in Plankton Section - Laboratory.

3. Calculations.

$$\text{Example: mg Chl/l} = \frac{(\text{extract conc. in mg/l}) \quad (\text{Vol. of acetone extract in liters})}{(2)(\text{area of slide in mm}^2)} = \text{mg/mm}^2$$

Then: $\text{mg/mm}^2 \times \text{factor} = \text{g/m}^2$

III. Cleaning of Glassware

A. Glassware should be washed with Alconox in hot water.

B. Rinse three times with tap water.

C. If rinse water does not drain freely leaving no droplets, rewash.

D. Rinse three times with distilled water.

E. Dry via air or oven.

Chl a = 11.6_{663}( ) - 2.16_{645}( ) - 0.10_{630}( ) =

Chl b = 20.97_{645}( ) - 3.94_{663}( ) - 3.66_{630}( ) =

Chl c = 54.22_{630}( ) - 5.53_{663}( ) - 14.81_{645}( ) =

Chl a = 11.6_{663}( ) - 2.16_{645}( ) - 0.10_{630}( ) =

Chl b = 20.97_{645}( ) - 3.94_{663}( ) - 3.66_{630}( ) =

Chl c = 54.22_{630}( ) - 5.53_{663}( ) - 14.81_{645}( ) =

Chl a = 11.6_{663}( ) - 2.16_{645}( ) - 0.10_{630}( ) =

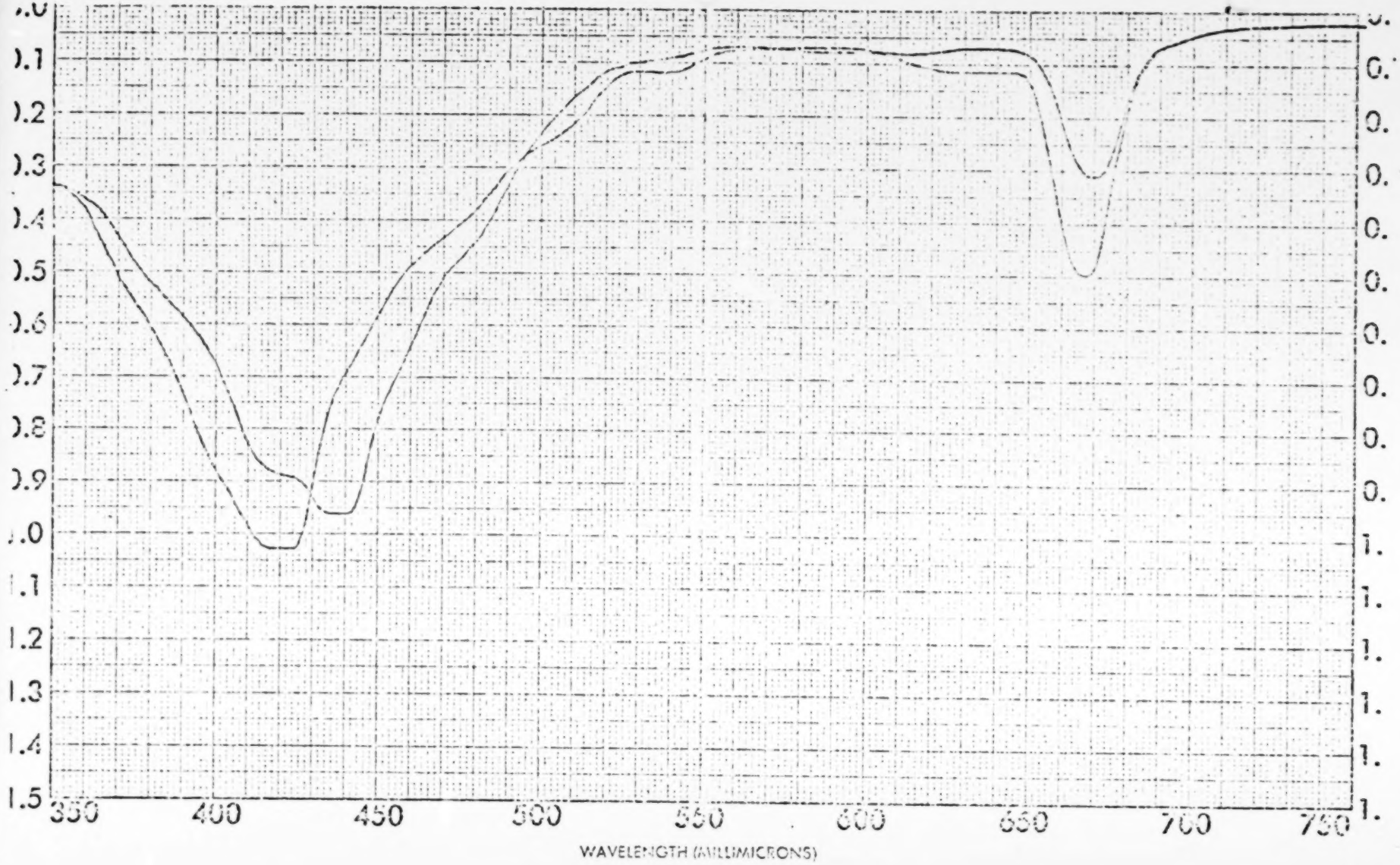
Chl b = 20.97_{645}( ) - 3.94_{663}( ) - 3.66_{630}( ) =

Chl c = 54.22_{630}( ) - 5.53_{663}( ) - 14.81_{645}( ) =

Chl a = 11.6_{663}( ) - 2.16_{645}( ) - 0.10_{630}( ) =

Chl b = 20.97_{645}( ) - 3.94_{663}( ) - 3.66_{630}( ) =

Chl c = 54.22_{630}( ) - 5.53_{663}( ) - 14.81_{645}( ) =



SAMPLE 71-400; CUM-109 North Tube # 22	CURVE NO. 45-114	SCAN SPEED SLOW	OPERATOR KCK
ORIGIN Cumberland R., Tenn.	CONC.	SLIT 2.5	DATE 12-13-71
SOLVENT 90% Ether + Acetone	CELL PATH 10 cm	REMARKS	
	REFERENCE 90% Acetone		

B-16

EPA
Plankton

Chlorophyll Data Sheet

I. IDENTIFYING INFORMATION

A. Log # _____
B. Station # _____
C. River or Lake _____
D. Date Collected _____
E. Graph Numbers _____ _____ _____ _____
F. Date of Determination _____
G. State _____
H. Method of Sample Collection & Handling _____
_____
_____

II. SPECTROPHOTOMETER DATA

A. Optical Density Readings:

1. Instrument Used: _____

Replicate	ml Filtered	Extract Volume	Dilution Factor	750	663b	645	630	663a	b/a
A									
B									
C									
D									

B. Chlorophyll Calculations:

Replicate	Concentration of Chlorophyll in Extract (mg/l)			Chlorophyll per Unit Volume (gm/m^3)			Chlorophyll per Unit Area (gm/m^2)		
	Chl a	Chl b	Chl c	Chl a	Chl b	Chl c	Chl a	Chl b	Chl c
A									
B									
C									
D									

C. Fluorimeter Data:

1. Instrument Used: _____
2. Fluorimeter Factor: _____

Replicate	Dilution Factor	Reading Before Acidification R	Reading Before Acidification S	b/a	Reading After Acidification R	Reading After Acidification S	Chl A gm/m^2
A							
B							
C							
D							

NOTE: R = Reading, S = Sensitivity Level

III. ASH FREE WEIGHT DATA

Replicate	Cruc #	C & D Weight	Dry Sample Weight	Fired Weight	Dry Weight	AFW	Organic Matter gm/m^2
A							
B							
C							
D							

NOTE: C&D = Clean & Dry, AFW = Ash Free Weight After Re-Wet

IV. REMARKS

_____
_____
_____

C-2

EPA
Periphyton

Chlorophyll Data Sheet

I. IDENTIFYING INFORMATION

A. Log # _____
B. Station # _____
C. River or Lake _____
D. Date Collected _____
E. Date of Determination _____
F. State _____
G. Method of Sample Collection & Handling ____
_____
_____

II. SPECTROPHOTOMETER DATA

A. Optical Density Readings:

1. Instrument Used: _____

Replicate	Extract Volume	Dilution Factor	750	663b	645	630	663a	b/a
A								
B								
C								
D								

B. Chlorophyll Calculations:

Replicate	Concentration of Chlorophyll in Extract (mg/l) Chl a	Chl b	Chl c	Area Scraped (mm^2)	Chlorophyll per Unit Area (gm/m^2) Chl a	Chl b	Chl c
A							
B							
C							
D							

C. Fluorimeter Data:

1. Instrument Used: _____
2. Fluorimeter Factor: _____

Replicate	Dilution Factor	Reading Before Acidification R	S	b/a	Reading After Acidification R	S	Chl a gm/m^2
A							
B							
C							
D							

NOTE: R = Reading, S = Sensitivity Level

III. ASH FREE WEIGHT DATA

Replicate	Cruc #	C & D Weight	Dry Sample Weight	Fired Weight	Dry Weight	AFW	Organic Matter gm/m^2
A							
B							
C							
D							

NOTE: C&D = Clean & Dry, AFW = Ash Free Weight After Re-Wet

IV. REMARKS

_____
_____
_____